Chapter

I BIOLOGY AND HUMAN BEHAVIOR

Nearly all general psychology texts begin with chapters relating to the biology of human behavior. This is due not simply to convention but rather because basic biological processes underlie *all* behavior. The various branches of psychology rest, to varying degrees, on this biological foundation. The area of psychology that studies these biological functions is typically called *psychobiology* or *biological psychology*. This field focuses on the actions of your brain and nervous system; the processes of receiving stimulation and information from the environment through your senses; the ways your brain organizes sensory information to create your perceptions of the world; and how all of this affects your body and behavior.

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 about how the brain functions. Next is a study that surprised the scientific community by demonstrating how a stimulating "childhood" might result in 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, along with several others in this book, also address an issue that underlies and connects nearly all areas of psychology and provides the fuel for an ongoing and fascinating debate: the nature–nurture controversy.

Reading 1: 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 example, in general the left side of your brain is responsible for movement in the right side of your body, and vice versa. Beyond this, though, the two brain hemispheres appear to have much greater specialized abilities.

It has come to be rather common knowledge that, for most of us, the left brain controls our ability to use language while the right is involved in spatial relationships, such as those needed for artistic activities. Stroke or head-injury patients who suffer damage to the left side of the brain will usually lose, to varying degrees, their ability to speak (often this skill returns with therapy 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 feeling emotions. The concepts underlying this view of the brain rest on early scientific research on the effects of splitting the brain into two separate hemispheres.

That research 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, in one series of studies, cats' brains were surgically altered to sever the connection between the two halves of the brain and to alter the optic nerves so that the left eye transmitted information only to the left hemisphere and the right eye only to the right hemisphere. Following surgery, the cats appeared to behave normally and exhibited virtually no ill effects. Then, with the right eye covered, the cats learned a new behavior, such as walking through a short maze to find food. After the cats became skilled at maneuvering through the maze, the eye cover was shifted to the cats' left eyes. Now, when the cats were placed back in the maze, their right brains had no idea where to turn and the animals had to relearn the entire maze from the beginning.

Sperry conducted many related studies over the next 30 years, and in 1981 he received the Nobel Prize for his work on the specialized abilities of the two hemispheres of the brain. When his research endeavors turned to human participants in the early 1960s, he was joined in his work at the California Institute of Technology (Caltech) by Michael Gazzaniga. Although Sperry is considered to be the founder of split-brain research, Gazzaniga's article has been chosen here because it is a clear, concise summary of their early collaborative work with human participants and it, along with other related research by Gazzaniga, is cited often in 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 discoveries 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 (Figure 1-1). If your corpus callosum is cut, this major line of communication is disrupted, and the two halves of your brain must then function independently. If we want to study each half of your brain separately, all we need to do is surgically sever your corpus callosum.

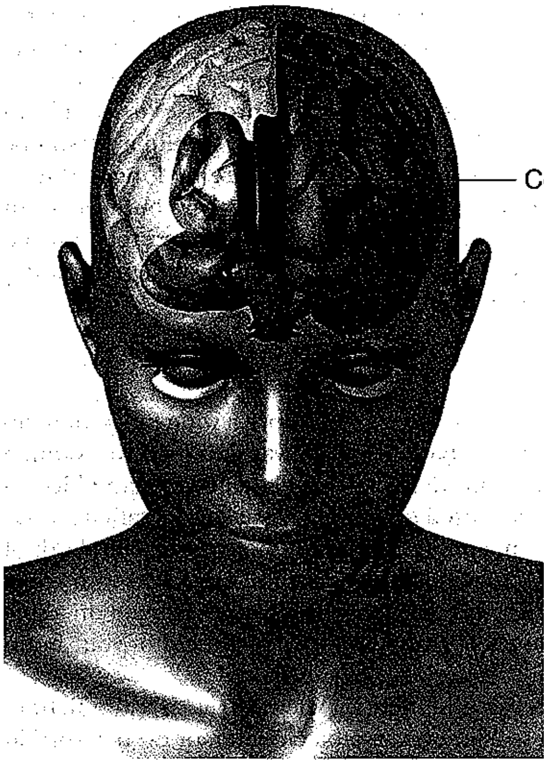

FIGURE 1-1 The Corpus Callosum. (Getty Images, Inc.)

But can scientists surgically divide the brains of humans for research purposes? That sounds more like a Frankenstein movie than real science! 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 greatly reduced or virtually eliminated by surgically severing the corpus callosum. This operation was (and is) 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 by 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, as well as 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? Considering that we receive sensory input from both the right and the left brains, 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 and perceptual capabilities of the patients. One was designed to examine visual abilities. They devised a technique that allowed 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 the right or the left visual field of your brain independently.

Another testing situation was designed for tactile (touch) stimulation. 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 participant 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 1-2).

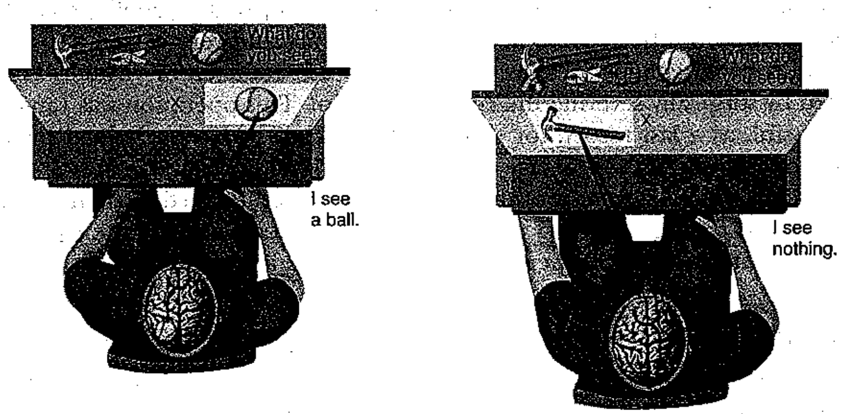

FIGURE 1-2 A typical visual testing device for split-brain participants.

Testing auditory abilities was somewhat trickier. 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 asked simply 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 these testing techniques to reveal some fascinating findings about how the brain functions.

RESULTS

First, 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. Gazzaniga reported that one patient, while still groggy from surgery, joked that he had "a splitting headache." When testing began, however, these participants 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 was 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, 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* in their right brain what the object was? To find out, the researchers asked the participants 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 could. 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 preceding findings and also offered additional interesting results. If participants were shown a picture of an object to the right hemisphere only, they were unable to name it or describe it. In fact, they might display no verbal response at all or even deny that anything had been presented. However, if the patients were allowed to reach under the screen with their left hand (still using only the right hemisphere) and touch a selection of objects, they were always able to find the one that had been presented visually.

The right hemisphere can 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 participants could touch 10 objects behind the screen, all of which 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 participants 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 participants could not name the word they had just spelled. Clearly, the left hemisphere 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 1-3, participants who copies three-dimensional drawings (using the pencil behind the screen) were much more successful when using the left hand.

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

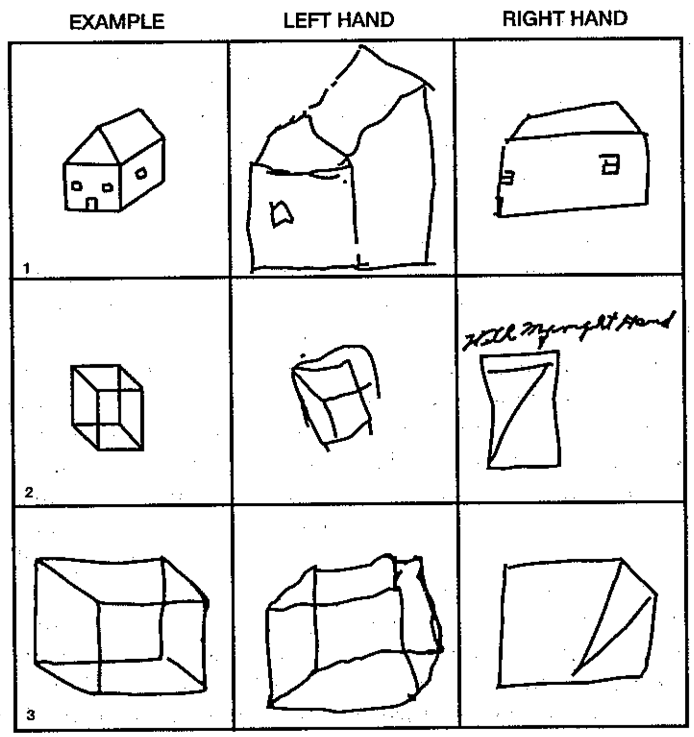

FIGURE 1-3 Drawings made by split-brain patients. (Adapted from p. 27, "The Split Brain in Man," by Michael S. Gazzaniga.)

DISCUSSION

The overall conclusion drawn from the research reported in this article was that two different brains exist 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, some research evidence suggests 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 subsequent research carried out by Sperry, Gazzaniga, and others were extremely significant and far-reaching. They demonstrated 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 it 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. In the years since Sperry and Gazzaniga's "split-brain" discoveries, psychobiological researchers have continued to uncover the amazing complexities of the human brain. Our brains are far more divided and compartmentalized than merely two hemispheres. We now know that a multitude of specific structures within the brain serve very specialized cognitive and behavioral functions.

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 a 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, suggested 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 racer* (Gazzaniga & LeDoux, 1978). Gazzaniga has taken this theory a step further. He has proposed that even in people whose brains are normal and intact, the two hemispheres may not be in complete communication (Gazzaniga, 1985). For example, if certain bits of information, such as those forming an emotion, are not stored in a linguistic 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. As this is an uncomfortable cognitive dilemma, the left hemisphere may try to *find* a verbal reason to explain the sadness (after all, language is its main job). However, because 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.

A widely believed myth states 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. Jerre Levy, a psychobiologist at the University of Chicago, has been in the forefront of scientists 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 the split-brain research by Sperry and Gazzaniga 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 the Sperry and Gazzaniga 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, including 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 participants 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 able to do so correctly only 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" to perceive their actions correctly.

Researchers continue to explore the idea that our two brain hemispheres have separate, yet distinct, functions and influences. One such study (Morton, 2003) demonstrated how your dominant hemisphere may lead you toward specific interests and professions. Morton's research made two discoveries in this regard. Using a special written test called "The Best Hand Test," which measures *hemisphericity* (whether a person is right- or left-brain oriented), Morton found that among 400 students enrolled in first-year, general college courses, 56% were left-brain oriented. However, when the same methods were applied to 180 students in various, *specialized* upper-level courses, the range of left brain students ranged from 38% to 65%. This difference indicated that something about a person's brain hemispheres was associated with spreading students out over a variety of college degrees and interests. Second, and more revealing, Morton employed the same method in determining the hemispheric orientation of members of various professions in university settings. The findings indicated that hemispheric specialization appears to be predictive of professional choices. For example, among biochemists Morton found that 83% were left-brain oriented, while among astronomers only 29% showed a left-brain preference (p. 319). You can see how this would make sense in relation to Sperry and Gazzaniga's work. Biology and chemistry rely more heavily on linguistic abilities, whereas astronomers must have greater abilities in spatial relationships (no pun intended).

CONCLUSION

Some have carried this, seperate-brain 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 it 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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Reading 2: MORE EXPERIENCE = BIGGER BRAIN

Rosenzweig, M. R., Bennett, E. L., & Diamond, M. C. (1972). Brain changes in response to experience. *Scientific American, 226* (2), 22–29.

If you were to enter the baby's room in a typical American middle-class home today, you would probably see a crib full of stuffed animals and various colorful toys dangling directly over or within reach of the infant. Some of these toys may light up, move, play music, or do all three. What do you suppose is the parents' reasoning behind providing infants with so much to see and do? Aside from the fact that babies seem to enjoy and respond positively to these toys, most parents' believe, whether they verbalize it or not, that children need a stimulating environment for optimal intellectual development and brain growth.

The question of whether certain experiences produce physical changes in the brain has been a topic of conjecture and research among philosophers and scientists for centuries. In 1785, Vincenzo Malacarne, an Italian anatomist, studied pairs of dogs from the same litter and pairs of birds from the same batches of eggs. For each pair, he would train one participant extensively over a long period of time while the other would be equally well cared for but untrained. He discovered later, in autopsies of the animals, that the brains of the trained animals appeared more complex, with a greater number of folds and fissures. However, this line of research was, for unknown reasons, discontinued. In the late 19th century, attempts were made to relate the circumference of the human head with the amount of learning a person had experienced. Although some early findings claimed such a relationship, later research determined that this was not a valid measure of brain development.

By the 1960s, new technologies had been developed that gave scientists the ability to measure brain changes with precision using high-magnification techniques and assessment of levels of various brain enzymes and neurotransmitter chemicals. Mark Rosenzweig and his colleagues Edward Bennett and Marian Diamond, at the University of California at Berkeley, incorporated those technologies in an ambitious series of 16 experiments over a period of 10 years to try to address the issue of the effect of experience on the brain. Their findings were reported in the article discussed in this chapter. For reasons that will become obvious, they did not use humans in their studies, but rather, as in many classic psychological experiments, their subjects were rats.

THEORETICAL PROPOSITIONS

Because psychologists are ultimately interested in humans, not rats, the validity of using nonhuman subjects must be demonstrated. In these studies, the authors explained that, for several reasons, using rodents rather than higher mammals such as primates was scientifically sound as well as more convenient. The part of the brain that is the main focus of this research is smooth in the rat, not folded and complex as it is in higher animals. Therefore, it can be examined and measured more easily. In addition, rats are small and inexpensive, which is an important consideration in the world of research laboratories (usually underfunded and lacking in space). Rats bear large litters, and this allows for members from the same litters to be assigned to different experimental conditions. The authors point out that various strains of inbred rats have been produced, and this allows researchers to include the effects of genetics in their studies if desired.

Implicit in Rosenzweig's research was the belief that animals raised in highly stimulating environments will demonstrate differences in brain growth and chemistry when compared with animals reared in plain or dull circumstances. In each of the experiments reported in this article, 12 sets of 3 male rats, each set from the same litter, were studied.

METHOD

Three male rats were chosen from each litter. They were then randomly assigned to one of three conditions. One rat remained in the laboratory cage with the rest of the colony; another was assigned to what Rosenzweig termed the "enriched" environment cage; and the third was assigned to the "impoverished" cage. Remember, 12 rats were placed in each of these conditions for each of the 16 experiments.

The three different environments (Figure 2-1) were described as follows:

1. The standard laboratory colony cage contained several rats in an adequate space with food and water always available.
2. The impoverished environment was a slightly smaller cage isolated in a separate room in which the rat was placed alone with adequate food and water.

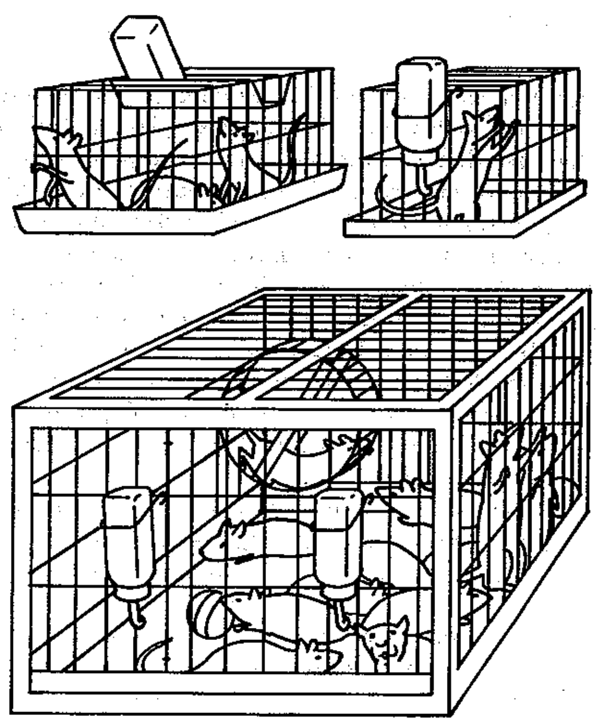

FIGURE 2-1 Rosenzweig's three cage environments.

3. The enriched environment was virtually a rat's Disneyland (no offense intended to Mickey!). Six to eight rats lived in a "large cage furnished with a variety of objects with which they could play. A new set of playthings, drawn out of a pool of 25 objects, was placed in the cage every day" (p. 22).

The rats were allowed to live in these different environments for various periods of time, ranging from 4 to 10 weeks. Following this differential treatment period, the experimental rodents were examined to determine if any differences had developed in brain development. To be sure that no experimenter bias would occur, the examinations were done in random order by code number so that the person doing the autopsy would not know in which condition the rat was raised.

The rats' brains were then measured, weighed, and analyzed to determine the amount of cell growth and levels of neurotransmitter activity. In this latter measurement, one brain enzyme was of particular interest: *acetylcholinesterase.* This chemical is important because it allows for faster and more efficient transmission of impulses among brain cells.

Did Rosenzweig and his associates find differences in the brains of rats raised in enriched versus impoverished environments? The following are their results.

RESULTS

Results indicated that the brains of the enriched rats were indeed different from those of the impoverished rats in many ways. The *cerebral cortex* (the part of the brain that responds to experience and is responsible for movement, memory, learning, and sensory input: vision, hearing, touch, taste, smell) of the enriched rats was significantly heavier and thicker. Also, greater activity of the nervous system enzyme acetylcholinesterase, mentioned previously, was found in the brain tissue of the rats with the enriched experience.

Although no significant differences were found between the two groups of rats in the number of brain cells (*neurons*), the enriched environment produced larger neurons. Related to this was the finding that the ratio of RNA to DNA, the two most important brain chemicals for cell growth, was greater for the enriched rats. This implied that a higher level of chemical activity had taken place in the enriched rats' brains.

Rosenzweig and his colleagues stated that "although the brain differences induced by environment are not large, we are confident that they are genuine. When the experiments are replicated, the same pattern of differences is found repeatedly . . . . The most consistent effect of experience on the brain that we found was the ratio of the weight of the cortex to the weight of the rest of the brain: the sub-cortex. It appears that the cortex increases in weight quite readily in response to experience, whereas the rest of the brain changes little" (p. 25). This measurement of the ratio of the cortex to the rest of the brain was the most accurate measurement of brain changes because the

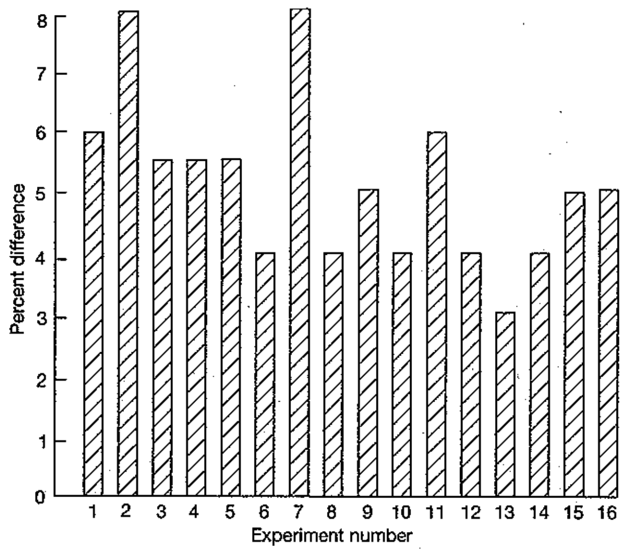

FIGURE 2-2 Ratio of cortex to the rest of the brain: enriched compared with impoverished environment. (Results in experiments 2 through 16 were statistically significant.) (Adapted from Rosenzweig, Bennett, & Diamond, p. 26.)

overall weight of the brain may vary with the overall weight of each animal. By considering this ratio, such individual differences are canceled out. Figure 2-2 illustrates this finding for all 16 studies. As you can see, in only one experiment was the difference *not* statistically significant.

The researchers reported a finding relating to the two rat groups' brain *synapses* (the points at which two neurons meet). Most brain activity occurs at the synapse, where a nerve impulse is either passed from one neuron to the next so that it continues on, or it is inhibited and stopped. Under great magnification using the electron microscope, the researchers found that the synapses of the enriched rats' brains were 50% larger than those of the impoverished rats, potentially allowing for increased brain activity.

DISCUSSION AND CRITICISMS

After nearly 10 years of research, Rosenzweig, Bennett, and Diamond were willing to state with confidence, "There can now be no doubt that many aspects of brain anatomy and brain chemistry are changed by experience" (p. 27). However, they were also quick to acknowledge that, when they first reported their findings, many other scientists were skeptical because such effects had not been so clearly demonstrated in past research. Some criticism contended that perhaps it was not the enriched environment that produced the brain changes but rather other differences in the treatment of the rats, such as mere handling or stress.

The criticism of differential handling was a valid one in that the enriched rats were handled twice each day when they were removed from the cage as the toys were being changed, but the impoverished rats were not handled. It was possible, therefore, that the handling alone might have caused the results and not the enriched environment. To respond to this potentially confounding factor, the researchers handled one group of rats every day and did not handle another group of their litter mates (all were raised in the same environment). Rosenzweig and his associates found no differences in the brains of these two groups. In addition, in their later studies, both the enriched and impoverished rats were handled equally and, still, the same pattern of results was found.

As for the criticisms relating to stress, the argument was that the isolation experienced by the impoverished rats was stressful, and this was the reason for their less-developed brains. Rosenzweig et al. cited other research that had exposed rats to a daily routine of stress (cage rotation or mild electric shock) and had found no evidence of changes in brain development due to stress alone.

One of the problems of any research carried out in a laboratory is that it is nearly always an artificial environment. Rosenzweig and his colleagues were curious about how various levels of stimulation might affect the brain development of animals in their *natural* environments. They pointed out that laboratory rats and mice often have been raised in artificial environments for as many as a hundred generations and bear little genetic resemblance to rats in the wild. To explore this intriguing possibility, they began studying wild deer mice. After the mice were trapped, they were randomly placed in either natural outdoor conditions or the enriched laboratory cages. After 4 weeks, the outdoor mice showed greater brain development than did those in the enriched laboratory environment. "This indicates that even the enriched laboratory environment is indeed impoverished in comparison with a natural environment" (p. 27).

The most important criticism of any research involving animal subjects is the question of its application, if any, to humans. Without a doubt, this line of research could never be performed on humans, but it is nevertheless the responsibility of the researchers to address this issue, and these scientists did so.

The authors explained that it is difficult to generalize from the findings of one set of rats to another set of rats, and consequently it is much more difficult to try to apply rat findings to monkeys or humans. And, although they report similar findings with several species of rodents, they admit that more research would be necessary before any assumptions could be made responsibly about the effects of experience on the human brain. They proposed, however, that the value of this kind of research on animals is that "it allows us to test concepts and techniques, some of which may later prove useful in research with human subjects" (p. 27).

Several potential benefits of this research were suggested by the authors. One possible application pertained to the study of memory. Changes in the brain due to experience might lead to a better understanding of how memories are stored in the brain. This could, in turn, lead to new techniques for improving memory and preventing memory loss due to aging. Another area in which this research might prove helpful was in explaining the relationship between malnutrition and intelligence. The concept proposed by the authors in this regard was that malnutrition may be a person's responsiveness to the stimulation available in the environment and consequently may limit brain development. The authors also noted that other studies suggested that the effects of malnutrition on brain growth may be either reduced by environmental enrichment or increased by deprivation.

RELATED RESEARCH AND RECENT APPLICATIONS

This work by Rosenzweig, Bennett, and Diamond has served as a catalyst for continued research in this developmental area that continues today. Over the decades since the publication of their article, these scientists and many others have continued to confirm, refine, and expand their findings. For example, research has demonstrated that learning itself is enhanced by enriched environmental experiences and that even the brains of adult animals raised in impoverished conditions can be improved when placed in an enriched environment (see Bennett, 1976, for a complete review).

Some evidence exists to indicate that experience does indeed alter brain development in humans. Through careful autopsies of humans who have died naturally, it appears that as a person develops a greater number of skills and abilities, the brain actually becomes more complex and heavier. Other findings have come from examinations during autopsies of the brains of people who were unable to have certain experiences. For example, in a blind person's brain, the portion of the cortex used for vision is significantly less developed, less convoluted, and thinner than in the brain of a person with normal sight.

Marian Diamond, one of the authors of this original article, has applied the results of work in this area to the process of human intellectual development throughout life. She says, "For people's lives, I think we can take a more optimistic view of the aging brain . . . . The main factor is stimulation. The nerve cells are designed for stimulation. And I think curiosity is a key factor. If one maintains curiosity for a lifetime, that will surely stimulate neural tissue and the cortex may in turn respond . . . . I looked for people who were extremely active after 88 years of age. I found that the people who use their brains don't lose them. It was that simple" (in Hopson, 1984, p. 70).

Two recent studies have elaborated on Rosenzweig, Diamond, and Bennett's notions of environmental influences on brain development in very diverse applications. Weiss and Bellinger (2006) expanded on the research by suggesting that studies of the effects of environmental toxins on early brain development in humans must encompass not only the toxicity of the chemical but also should consider all the factors present within the individual's overall life context, including genetic tendencies and enriched or impoverished environments. The authors proposed that, in humans, the effects of exposure to toxic substances tends to be directly related to growing up in an enriched versus an impoverished environment. In other words, when children are raised in poverty, not only is their developmental environment likely to be impoverished, but they may also be at a greater risk of exposure to neurotoxic chemicals. Moreover, the environmental factors that are present can affect the outcome of the toxic exposure on brain development. Weiss and Bellinger asserted that when researchers have studied environmental toxins, the tendency has been to focus on the toxic substance itself and to minimize the accompanying situational variables. As the authors stated:

> We argue that the outcomes of exposure to neurotoxic chemicals early in life are shaped by the nature of a child's social environment, including that prevailing before birth . . . . We contend that a true evaluation of toxic potential and its neurobehavioral consequences is inseparable from the ecologic setting [such as environmental richness] in which they act and which creates unique, enduring individual vulnerabilities." (p. 1497)

Another article cites Rosenzweig's 1972 study in critiquing some recent attempts to oversimplify enrichment strategies in attempts to enhance children's brain development (Jones & Zigler, 2002). As you can imagine, when the public learns about research such as Rosenzweig's, a popular movement may be born that sounds attractive but has little basis in scientific fact. One of these from the 1990s, which you may have heard about, has become known as the "Mozart Effect." This fad began with some preliminary research showing that when children listen to Mozart (but not other classical composers) they become better learners. This idea has grown to the point that entire Web sites are devoted to the benefits of the "Mozart Effect" for children and adults alike, involving claims that certain music can enhance overall health, improve memory, treat attention deficit disorder, reduce depression, and speed healing from physical injuries.

CONCLUSION

Jones and Zigler (2002) maintain that such popular applications of the research are ineffective and even dangerous. They contend, "Brain research is being misappropriated to the service of misguided 'quick fix' solutions to more complicated, systemic issues" (p. 355). They further suggest that when scientific brain and learning research is applied carefully and correctly, it can make a "substantive contribution of high quality, intensive, multidomain interventions to early cognitive and social development" (p. 355).

Bennett, E. L. (1976). Cerebral effects of differential experience and training. In M. R. Rosenzweig & E. L. Bennett (Eds.), *Neural mechanisms of learning and memory.* Cambridge, MA: MIT Press.

Hopson, J. (1984). A love affair with the brain: A PT conversation with Marian Diamond. *Psychology Today, 11,* 62–75.

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Weiss, B., & Bellinger, D. C. (2006). Social ecology of children's vulnerability to environmental pollutants. (Commentary). *Environmental Health Perspectives, 114,* 1479–1485.

Reading 3: ARE YOU A "NATURAL?"

Bouchard, T., Lykken, D., McGue, M., Segal, N., & Tellegen, A. (1990). Sources of human psychological differences: The Minnesota study of twins reared apart. *Science, 250,* 223–229.

This study represents a relatively recent and ongoing fundamental change in the way many psychologists view human nature in its broadest sense. You can relate to this change in a personal way by first taking a moment to answer in your mind the following question: "Who are you?" Think for a moment about some of your individual characteristics: your "personality traits." Are you high strung or laid-back? Are you shy or outgoing? Are you adventurous, or do you seek out comfort and safety? Are you easy to get along with, or do you tend toward the disagreeable? Are you usually optimistic or more pessimistic about the outcome of future events? Think about yourself in terms of these or any other questions you feel are relevant. Take your time . . . . Finished? Now, answer this next, and, for this reading, more important question: "*Why* are you who you are?" In other words, what factors contributed to "creating" this person you are today?

If you are like most people, you will point to the child-rearing practices of your parents and the values, goals, and priorities they instilled in you. You might also credit the influences of brothers, sisters, grandparents, aunts, uncles, peers, teachers, and other mentors who played key roles in molding you. Still others of you will focus on key life-changing events, such as an illness, the loss of a loved one, or the decision to attend a specific college, choose a major, or take a particular life course that seemed to lead you toward becoming your current self. All these influences share one characteristic: they are all *environmental* phenomena. Hardly anyone ever replies to the question "Why are you who you are?" with "I was born to be who I am; it's all in my genes."

Everyone acknowledges that physical attributes, such as height, hair color, eye color, and body type, are genetic. More and more people are realizing that tendencies toward many illnesses, such as cancer, heart disease, and high blood pressure, have significant genetic components. However, almost no one thinks of genes as the main force behind who they are *psychologically.* This may strike you as odd when you stop to think about it, but in reality very understandable reasons explain our "environmental bias."

First of all, psychology during the second half of the 20th century was dominated by the *behaviorism* theory of human nature. Basically, that theory states that all human behavior is controlled by environmental factors, including the stimuli that provoke behaviors and the consequences that follow response choices. Strict behaviorists believed that the internal psychological workings of the human mind were not only impossible to study scientifically but, also, that such study was unnecessary and irrelevant to a complete explanation for human behavior. Whether the wider culture accepted or even understood formal theories of behaviorism is not as important as the reality of their influence on today's firmly entrenched popular belief that *experience* is the primary or exclusive architect of human nature.

Another understandable reason for the pervasive acceptance of environmental explanations of behavior is that genetic and biological factors do not provide visible evidence of their influence. It's easy for someone to say "I became a writer because I was deeply inspired and encouraged by my seventh-grade composition teacher." You remember those sorts of influences; you see them; they are part of your past and present conscious experiences. You would find it much more difficult to recognize biological influences and say "I became a writer because my DNA contains a gene that has been expressed in me that predisposes me to write well." You can't see, touch, or remember the influence of your genes, and you don't even know where in your body they might be located!

In addition, many people are uncomfortable with the idea that they might be the product of their genes rather than the choices they have made in their lives. Such ideas smack of determinism and a lack of free will. Most people have a strong dislike for any theory that might in some way limit their conscious ability to determine the outcomes in their lives. Consequently, genetic causes of behavior and personality tend to be avoided or rejected. In reality, genetic influences interact with experience to mold a complete human, and the only question is this: Which is more dominant? Or, to phrase the question as it frequently appears in the media, *"Is it nature or nurture?"*

The article by Thomas Bouchard, David Lykken, and their associates at the University of Minnesota in Minneapolis that is referenced in this chapter is a review of research that began in 1979 to examine the question of how much influence your genes have in determining your personal psychological qualities. This research grew out of a need for a scientific method to separate genetic influences (nature) from environmental forces (nurture) on people's behavior and personality. This is no simple task when you consider that nearly every one of you, assuming you were not adopted, grew and developed under the direct environmental influence of your genetic donors (your parents). You might, for example, have the same sense of humor as your father (no offense!) because you learned it from him (nurture) or because you inherited his "sense-of-humor" gene (nature). No systematic approach can tease those two influences apart, right?

Well, Bouchard and Lykken would say "wrong." They have found a way to determine with a reasonable degree of confidence which psychological characteristics appear to be determined primarily by genetic factors and which are molded more by your environment.

THEORETICAL PROPOSITIONS

It's simple, really. All you have to do is take two humans who have exactly the same genes, separate them at birth, and raise them in significantly different environments. Then you can assume that those behavioral and personality characteristics they have in common as adults must be genetic. But how on earth can researchers possibly find pairs of *identical people* (don't say "cloning"; we're not there yet!)? And even if they could, it would be unethical to force them into diverse environments, wouldn't it? As you've already guessed, the researchers didn't have to do that. Society had already done it for them. Identical twins have virtually the same genetic structure. They are called *monozygotic twins* because they start as one fertilized egg, called a *zygote*, and then split into two identical embryos. Fraternal twins are the result of two separate eggs fertilized by two separate sperm cells and are referred to as *dizygotic twins*. Fraternal twins are only as genetically similar as any two non-twin siblings. As unfortunate as it sounds, twin infants are sometimes given up for adoption and placed in separate homes. Adoption agencies will try to keep siblings, especially twins, together, but the more important goal is to find good homes for them even if it means separation. Over time, thousands of identical and fraternal twins have been adopted into separate homes and raised, frequently without the knowledge that they were a twin, in different and often contrasting environmental settings.

In 1983 Bouchard and Lykken began to identify, locate, and bring together pairs of these twins. This 1990 article reports on results from 56 pairs of monozygotic reared-apart (MZA) twins from the United States and seven other countries who agreed to participate in weeklong sessions of intensive psychological and physiological tests and measurements (that this research is located in Minneapolis, one half of "the Twin Cities" is an irony that has not, by any means, gone unnoticed). These twins were compared with monozygotic twins reared together (MZT). The surprising findings continue to reverberate throughout the biological and behavioral sciences.

METHOD

Participants

The first challenge for this project was to find sets of monozygotic twins who were separated early in life, reared apart for all of most of their lives, and reunited as adults. Most of the participants were found through word of mouth as news of the study began to spread. The twins themselves or their friends or family members would contact the research institute, the Minnesota Center for Twin and Adoption Research (MICTAR), various social-services professionals in the adoption arena would serve as contacts, or, in some cases one member of a twin-pair would contact the center for assistance in locating and reuniting with his or her sibling. All twins were tested to ensure that they were indeed monozygotic before beginning their participation in the study.

Procedure

The researchers wanted to be sure they obtained as much data as possible during the twins' one-week visit. Each twin completed approximately 50 hours of testing on nearly every human dimension you might imagine. They completed four personality trait scales, three aptitude and occupational interest inventories, and two intelligence tests. In addition, the participants filled in checklists of household belongings (such as power tools, telescope, original artwork, unabridged dictionary), to assess the similarity of their family resources, and a family environment scale that measured how they felt about the parenting they received from their adoptive parents. They were also administered a life history interview, a psychiatric interview, and a sexual history interview. All these assessments were carried out individually so that it was not possible for one twin to inadvertently influence the answers and responses of the other.

As you might imagine, the hours of testing created a huge database of information. The most important and surprising results are discussed here.

RESULTS

Table 3-1 summarizes the similarities for some of the characteristics measured in the monozygotic twins reared apart (MZA) and includes the same data for monozygotic twins reared together (MZT). The degree of similarity is expressed in the table as correlations or *r* values. The larger the correlation, the greater the similarity. The logic here is that if environment is responsible for individual differences, the MZT twins who shared the same environment as they grew up *should be* significantly more similar than the MZA twins. As you can see, this is not what the researchers found.

TABLE 3-1 Comparison of Correlations (*r*) of Selected Characteristics for Identical Twins Reared Apart (MZA) and Identical Twins Reared Together (MZT)*

CHARACTERISTIC	*r* (MZA)	*r* (MZT)	SIMILARITY *r* (MZA) ÷ *r* (MZT)**
Physiological	—	—	—
Brain wave activity	.80	.81	.987
Blood pressure	.64	.70	.914
Heart rate	.49	.54	.907
Intelligence	—	—	—
WAIS IQ	.69	.88	.784
Raven Intelligence Test	.78	.76	1.03
Personality	—	—	—
Multidimensional Personality Questionnaire (MPQ)	.50	.49	1.02
California Personality Inventory	.48	.49	.979
Psychological interests	—	—	—
Strong Campbell Interest Inventory	.39	.48	.813
Minnesota Occupational Interest Scale	.40	.49	.816
Social attitudes	—	—	—
Religiosity	.49	.51	.961
Nonreligious social attitudes	.34	.28	1.21

*Adapted from Table 4, p. 226.

**1.00 would imply that MZA twin pairs were found to be exactly as similar as MZT twin pairs.

The last column in Table 3-1 expresses the difference in similarity by dividing the MZA correlation on each characteristic by the MZT correlation. If both correlations were the same, the result would be 1.00; if they were entirely dissimilar, the result could be as low as 0.00. Examining column 4 in the table carefully, you'll find that the correlations for characteristics were remarkably similar—that is, close to 1.00 and no lower than .700 for MZA and MZT twin pairs.

DISCUSSION AND IMPLICATIONS OF FINDINGS

These findings indicate that genetic factors (or the *genome*) appear to account for most of the variations in a remarkable variety of human characteristics. This finding was demonstrated by the data in two important ways. One is that genetically identical humans (monozygotic twins), who were raised in separate and often very different settings, grew into adults who were extraordinarily similar, not only in appearance but also in basic psychology and personality. The second demonstration in this study of the dominance of genes is the fact that there appeared to be *little* effect of the environment on identical twins who *were* raised in the same setting. Here's Bouchard and Lykken's take on these discoveries:

> For almost every behavioral trait so far investigated, from reaction time to religiosity, an important fraction of the variation among people turns out to be associated with genetic variation. This fact need no longer be subject to debate; rather, it is time to consider its implications.

Of course, some will argue with Bouchard and Lykken's notion that the time to debate these issues is over. Some varying views are discussed in the next section. However, a discussion of the implications of this and other similar studies by these same researchers is clearly warranted. In what ways do the genetic findings reported in this study change psychologists' and, for that matter, all of our views of human nature? As mentioned previously, psychology and Western culture have been dominated for over 50 years by environmental thinking. Many of our basic beliefs about parenting, education, crime and punishment, psychotherapy, skills and abilities, interests, occupational goals, and social behavior, just to name a few, have been interpreted from the perspective that people's experience molds their personalities, not their genes. Very few of us look at someone's behavior and think, "That person was *born* to behave like that!" We *want* to believe that people *learned* their behavior patterns because that allows us to feel some measure of confidence that parenting makes a difference, that positive life experiences can win out over negative ones, and that unhealthy, ineffective behaviors can be *unlearned*. The notion that personality is a done deal the moment we are born leaves us with the temptation to say "Why bother?" Why bother working hard to be good parents? Why bother trying to help those who are down and out? Why bother trying to offer quality education? And so on. Bouchard and Lykken would want to be the first to disagree with such an interpretation of their findings. In this article, they offer three of their own implications of their provocative conclusions:

1. Clearly, intelligence is primarily determined by genetic factors (70% of the variation in intelligence appears to be due to genetic influence). However, as the authors state very clearly,

   > [T]hese findings do not imply that traits like IQ cannot be enhanced . . . . A survey covering 14 countries has shown that the average IQ test score has increased in recent years. The present findings, therefore, do not define or limit what might be conceivably achieved in an optimal environment. (p. 227)

   Basically, what the authors are saying is that although 70% of the variation in IQ is due to naturally occurring genetic variation, 30% of the variation remains subject to increases or decreases due to environmental influences. These influences include many that are well known, such as education, family setting, toxic substances, and socioeconomic status.
2. The basic underlying assumption in Bouchard and Lykken's research is that human characteristics are determined by some combination of genetic and environmental influences. When the environment exerts less influence, differences must be attributed more to genes. The converse is also true: as environmental forces create a stronger influence on differences in a particular characteristic, genetic influences will be weaker. For example, most children in the United States have the opportunity to learn to ride a bicycle. This implies that the environment's effect on bicycle riding is somewhat similar for all children, so differences in riding ability will be more affected by genetic forces. On the other hand, variation in, say, food preferences in the United States are more likely to be explained by environmental factors because food and taste experiences in childhood and throughout life are very diverse and will, therefore, leave less room for genetic forces to function. Here's the interesting part of the researchers' point: they maintain that personality is more like bicycle riding than food preferences.

   The authors are saying, in essence, that family environments exert *less* influence over who the kids grow up to be than do the genes they inherit from birth. Understandably, most parents do not want to hear or believe this. They are working hard to be good parents and to raise their children to be happy individuals and good citizens. The only parents who might take some comfort from these findings are those who are nearing their wits' end with out-of-control or incorrigible sons or daughters and would appreciate being able to take less of the blame! However, Bouchard and Lykken are quick to point out that genes are not necessarily destiny and that devoted parents can still influence their children in positive ways, even if they are only working on a small percentage of the total variation.

3. The most intriguing implication that Bouchard and Lykken suggest is that it's not the environment influencing people's characteristics, but vice versa. That is, people's genetic tendencies actually mold their environments! The following is an example of the idea behind this theory.

   The fact that some people are more affectionate than others is usually seen as evidence that some parents were more affectionate with their children than were other parents. In other words, affectionate kids come from affectionate environments. When this kind of assumption has been studied, it is usually found to be true. Affectionate people have, indeed, received more affection from their parents. Bouchard and Lykken are proposing, however, that variation in "affectionateness" may be, in reality, genetically determined so that some children are just born more affectionate than others. Their inborn tendency toward affectionate behavior causes them to *respond* to affection from their parents in ways that reinforce the parents' behavior much more than genetically nonaffectionate children. This, in turn *produces* the affectionate behavior in the parents, not the other way around. The researchers contend that genes function in this way for many, if not most, human characteristics. They state it this way:

   > The proximal [most immediate] cause of most psychological variance probably involves learning through experience, just as radical environmentalists have always believed. The effective experiences, however, to an important extent are self-selected, and that selection is guided by the steady pressure of the genome. (p. 228)

CRITICISMS AND RELATED RESEARCH

As you might imagine, a great many related studies have been carried out using the database of twins developed by Bouchard and Lykken. In general, the findings continue to indicate that many human personality characteristics and behaviors are strongly influenced by genes. Many attributes that have been seen as stemming largely or completely from environmental sources are being reevaluated as twin studies reveal that heredity contributes either the majority of the variation or a significantly larger proportion than was previously contemplated.

For example, studies from the University of Minnesota team found not only that the vocation you choose is largely determined by your genes but also that about 30% of the variation in your overall job satisfaction and work ethic appears due to genetic factors (Arvey et al., 1989; Arvey et al., 1994) even when the physical requirements of various professions were held constant. Other studies comparing identical (monozygotic) twins with fraternal (dizygotic) twins, both reared together and reared apart, have focused more directly on specific personality traits that are thought to be influential and stable in humans (Bouchard, 1994; Loehlin, 1992). These and other studies' findings determined that the people's variation on the characteristics of extraversion–introversion (outgoing versus shy), neuroticism (tendency to suffer from high anxiety and extreme emotional reactions), and conscientiousness (degree to which a person is competent, responsible, and thorough) is explained more (65%) by genetic differences than by environmental factors.

Of course, not everyone in the scientific community is willing to accept these findings at face value. The criticisms of Bouchard and Lykken's work take several directions (see Billings et al., 1992). Some studies claim that the researchers are not publishing their data as fully and completely as they should, and, therefore, their findings cannot be independently evaluated. These same critics also claim that many articles are reporting on case studies demonstrating strong environmental influences on twins that Bouchard and Lykken fail to consider.

In addition, some researchers have voiced a major criticism of one aspect of twin research in general, referred to as the "equal environment assumption" (e.g., Joseph, 2002). This argument maintains that many of the conclusions drawn by Bouchard and Lykken about genetic influence assume that monozygotic and dizygotic twins raised together develop in identical environments. These critics maintain that such an assumption is not valid and that fraternal twins are treated far more differently than are identical twins. This, they contend, draws the entire method of twin research as a determinant of genetic influences into question. However, several other articles have refuted this criticism and supported the "equal environment assumption" (e.g., Kendler et al., 1993).

RECENT APPLICATIONS

In 1999, Bouchard reviewed the nature–nurture evidence from the Minnesota twin registries (Bouchard, 1999). He concluded that, overall, 40% of the variability in personality and 50% of the variability in intelligence appears to be genetically based. He also reiterated his position, discussed previously, that your genes drive your selection of environments and your selection or avoidance of specific personality-molding environments and behaviors.

Research at the Minnesota Center for Twin and Adoption Research continues to be very active. Some fascinating research has examined very complex human characteristics and behaviors that few would have even guessed to be genetically driven, such as love, divorce, and even death (see Minnesota Twin Family Study, 2007). They have studied people's selection of a mate to see if "falling in love" with Mr. or Ms. Right is genetically predisposed. It turns out that it is not. However, the researchers have found a genetic link to the likelihood of divorce, eating disorders, and age at the time of death.

Bouchard and Lykken's research has been applied to the larger philosophical discussion of human cloning (see Agar, 2003). If a human being is ever successfully cloned, the question is, as you are probably thinking, to what extent will a person's essence, an individual's *personality,* be transferred to his or her clone? The fear that human identity might be changed, degraded, or lost has been a common argument of those opposed to cloning. On the other hand, results of twin studies, such as those of Bouchard and Lykken suggest that "the cloned person may, under certain circumstances, be seen as surviving, to some degree, in the clone.... However... rather than warranting concern, the potential for survival by cloning ought to help protect against the misuse of the technology" (Agar, 2003, p. 9). In a separate study examining the issue of identical twins and cloning (Prainsack & Spector, 2006), researchers found that identical twins rarely consider the genetic aspects of their real-life experience of being identical twins. In addition, from a personal perspective, they did not view the idea of human cloning as unnatural or immoral but were more concerned about the ethics underlying the *reasons* for human cloning. Of course, this is philosophical discussion so far, but as the prospect of human cloning looms ever closer, it becomes increasingly important and interesting food for thought.

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Reading 4: WATCH OUT FOR THE VISUAL CLIFF!

Gibson, E. J., & Walk, R. D. (1960). The "visual cliff." *Scientific American, 202*(4), 67–71.

One of the most often told anecdotes in psychology concerns a man called S. B. (initials used to protect his privacy). S. B. had been blind his entire life until the age of 52, when he underwent a newly developed operation (the now-common corneal transplant) and his sight was restored. However, S. B.'s new ability to see did not mean that he automatically perceived what he saw the way the rest of us do. One important example of this became evident soon after the operation, before his vision had cleared completely. S. B. looked out his hospital window and was curious about the small objects he could see moving on the ground below. He began to crawl out on his window ledge, thinking he would lower himself down by his hands and have a look. Fortunately, the hospital staff prevented him from trying this. He was on the fourth floor, and those small moving things were cars! Even though S. B. could now see, he was not able to perceive depth.

Our visual ability to sense and interpret the world around us is an area of interest to experimental psychologists because, obviously, it affects our behavior in important ways. In addition, within this ability lies the central question of whether our sensory processes are inborn or learned: the nature–nurture issue once again. Many psychologists believe that our most important visual skill is depth perception. You can imagine how difficult, and probably impossible, survival of the human species would have been if we could not perceive depth. We might have run headlong into things, been unable to judge how far away a predator was, or stepped right off cliffs. Therefore, it might be logical to assume that depth perception is an inborn survival mechanism that does not require experience to develop. However, as Eleanor Gibson and Richard Walk point out in their article:

> Human infants at the creeping and toddling stage are notoriously prone to falls from more or less high places. They must be kept from going over the brink by side panels on their cribs, gates on stairways, and the vigilance of adults. As their muscular coordination matures, they begin to avoid such accidents on their own. Common sense might suggest that the child learns to recognize falling-off places by experience—that is, by falling and hurting himself" (p. 64).

These researchers wanted to study this visual ability of depth perception scientifically in the laboratory. To do this, they conceived of and developed a remarkable research tool they called the *visual cliff.*

THEORETICAL PROPOSITIONS

If you wanted to find out at what point in the early developmental process animals or people are able to perceive depth, one way to do this would be to put them on the edge of a cliff and see if they are able to avoid falling off. This is a ridiculous suggestion because of the ethical considerations of the potential injury to participants who were unable to perceive depth (or, more specifically, height). The *visual cliff* avoids this problem because it presents the participant with what appears to be a drop-off, when no drop-off actually exists. Exactly how this is done will be explained shortly, but it is important first to recognize that the importance of this apparatus lies in the fact that human or animal infants can be placed on the visual cliff to see if they are able to perceive the drop-off and avoid it. If they are unable to do this and step off the "cliff," there is no danger of falling.

Gibson and Walk took a "nativist" position on this topic: they believed that depth perception and the avoidance of a drop-off appear automatically as part of our original biological equipment and are not, therefore, products of experience. The opposing view, held by empiricists, contends that such abilities are learned. Gibson and Walk's visual cliff allowed them to ask these questions: At what stage in development can a person or animal respond effectively to the stimuli of depth and height? Do these responses appear at different times with animals of different species and habitats? Are these responses preprogrammed at birth or do they develop as a result of experience and learning?

METHOD

The visual cliff is comprised of a table about 4 feet high with a top made from a piece of thick, clear glass (Figures 4-1 and 4-2). Directly under half of the glass on the table (the shallow side) is a solid surface with a red-and-white checkered pattern. Under the other half is the same pattern, but it is down at the level of the floor underneath the table (the deep side). At the edge of the shallow side, then, is the appearance of a sudden drop-off to the floor, although, in reality, the glass extends all the way across. Between the shallow and the deep sides is a center board about a foot wide. The process of testing infants using this device was extremely simple.

The participants for this study were 36 infants between the ages of 6 months and 14 months. The mothers of the infants also participated. Each infant was placed on the center board of the visual cliff and was then called by the mother, first from the deep side and then from the shallow side.

To compare the development of depth perception in humans with that in other baby animals, the visual cliff allowed for similar tests with other

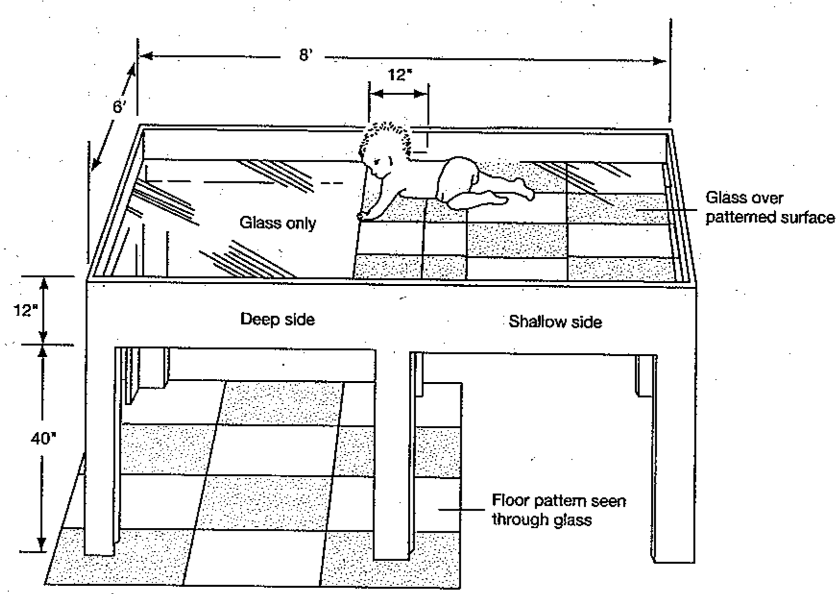

FIGURE 4-1 Gibson and Walk's visual cliff. From *Introduction to Child Development* (5th ed.), by J. Dworetzky (c) 1993. Reprinted with permission of Wadsworth, an imprint of the Wadsworth Group, a division of Thomson Learning.

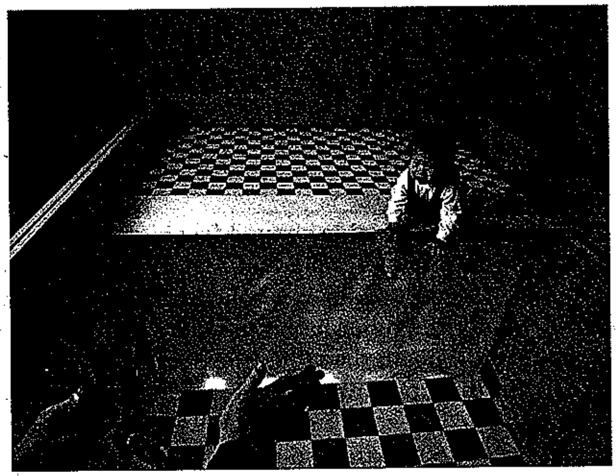

FIGURE 4-2 The visual cliff in a testing situation. (Mark Richards/PhotoEdit/Courtesy of Joe Campos & Rosanne Kermoian.)

species (without a mother's beckoning, however). The baby animals were placed on the center board and observed to see if they could discriminate between the shallow and deep sides and avoid stepping off "the cliff." You can imagine the rather unique situation in the psychology labs at Cornell University when the various baby animals were brought in for testing. They included chicks, turtles, rats, lambs, kids (baby goats, that is), pigs, kittens, and puppies. One has to wonder if they were all tested on the same day!

Remember that the goal of this research was to examine whether depth perception is learned or innate. What makes this method so ingenious is that it allowed that question to at least begin to be answered. Infants, whether human or animal, cannot be *asked* if they perceive depth, and, as mentioned, human infants cannot be tested on real cliffs. In psychology, answers to perplexing questions are often found through the development of new methods for studying the questions. The results of Gibson and Walk's early study provide an excellent example of this.

RESULTS AND DISCUSSION

Nine children in the study refused to move at all off the center board. This was not explained by the researchers, but perhaps it was just infant stubbornness. When the mothers of the other 27 called to them from the shallow side, all the infants crawled off the board and crossed the glass. Only three of them, however, crept, with great hesitation, off the brink of the visual cliff when called by their mothers from the deep side. When called from the "cliff" side, most of the children either crawled away from the mother on the shallow side or cried in frustration at being unable to reach the mother without moving over the "cliff." There was little question that the children were perceiving the depth of the "cliff." "Often they would peer down through the glass of the deep side and then back away. Others would pat the glass with their hands, yet despite this tactile assurance of solidity would refuse to cross" (p. 64).

Do these results prove that humans' ability to perceive depth is innate rather than learned? It does not, because all the children in this study had at least 6 months of life experience in which to learn about depth through trial and error. However, human infants cannot be tested in this way prior to 6 months of age because they do not have adequate locomotor abilities. It was for this reason that Gibson and Walk decided to test various other animals as a comparison. As you know, most nonhuman animals gain the ability to move about much sooner than humans. The results of the animal tests were extremely interesting, in that the ability of the various animals to perceive depth developed in relation to when the species needed such a skill for survival.

For example, baby chickens must begin to scratch for their own food soon after hatching. When they were tested on the visual cliff at less than 24 hours of age, they never made the mistake of stepping off onto the deep side.

Kids and lambs are able to stand and walk very soon after birth. From the moment they first stood up, their response on the visual cliff was as accurate and predictable as that of the chicks. Not one error was made. When one of the researchers placed a one-day-old baby goat on the deep side of the glass, the goat became frightened and froze in a defensive posture. If it was then pushed over the shallow side, it would relax and jump forward onto the seemingly solid surface. This indicated that the visual sense was in complete control and that the animals' ability to feel the solidity of the glass on the deep side had no effect on the response.

For the rats, it was a different story. They did not appear to show any significant preference for the shallow side of the table. Why do you suppose this difference was found? Before you conclude that rats are just stupid, consider Gibson and Walk's much more likely explanation: a rat does not depend very much on vision to survive. Because it is nocturnal, a rat locates food by smell and moves around in the dark using cues from the stiff whiskers on its nose. So when a rat was placed on the center board, it was not fooled by the visual cliff because it was not using vision to decide which way to go. To the rat's whiskers, the glass on the deep side felt the same as the glass on the shallow side and, thus, the rat was just as likely to move off the center board to the deep side as to the shallow side.

You might expect the same results from kittens. They are basically nocturnal and have sensitive whiskers. However, cats are predators, not scavengers like rats. Therefore, they depend more on vision. And, accordingly, kittens were found to have excellent depth perception as soon as they were able to move on their own: at about 4 weeks.

Although at times this research article, and this discussion, risk sounding like a children's animal story, it has to be reported that the species with the worst performance on the visual cliff was the turtle. The baby turtles chosen to be tested were of the aquatic variety because the researchers expected that they might prefer the deep side of the "cliff" because their natural environment is water. However, it appeared that the turtles were "smart" enough to know that they were not in water: 76% of them crawled off onto the shallow side, while 24% went "over the edge." "The relatively large minority that chose the deep side suggests either that this turtle has poorer depth perception than other animals, or its natural habitat gives it less occasion to 'fear' a fall" (p. 67). Clearly, if you live your life in water, the survival value of depth perception, in terms of avoiding falls, would be diminished.

Gibson and Walk pointed out that all of their observations were consistent with evolutionary theory. That is, all species of animals, if they are to survive, need to develop the ability to perceive depth by the time they achieve independent movement. For humans, this does not occur until around 6 months of age; but for chickens and goats it is nearly immediate (by 1 day old); and for rats, cats, and dogs, it is about 4 weeks of age. The authors conclude, therefore, that this capacity is inborn because to learn it through trial and error would cause too many potentially fatal accidents.

If we are so well prepared biologically, why do children take so many falls? Gibson and Walk explained that the human infants' perception of depth had matured sooner than had their skill in movement. During testing, many of the infants supported themselves on the deep side of the glass as they turned on the center board, and some even backed up onto the deep side as they began to crawl toward the mother across the shallow side. If the glass had not been there, some of the children would have fallen off the "cliff"!

CRITICISMS AND SUBSEQUENT RESEARCH

The most common criticism of the researchers' conclusions revolves around the question of whether they really proved that depth perception is innate in humans. As mentioned, by the time infants were tested on the visual cliff, they had already learned to avoid such situations. A later study placed younger infants, ages 2 to 5 months, on the glass over the deep side of the visual cliff. When this happened, all the babies showed a decrease in heart rate. Such a decrease is thought to be a sign of interest, not fear, which is accompanied by heart rate increases (Campos et al., 1978). This indicates that these younger infants had not yet learned to fear the drop-off and would learn the avoidance behavior somewhat later. These findings argued against Gibson and Walk's position.

It is important to notice, however, that although there was and still is controversy over just when we are able to perceive depth (the nativists vs. the empiricists), much of the research that is done to find the answer incorporates the visual cliff apparatus developed by Gibson and Walk. In addition, other related research using the visual cliff has turned up some fascinating findings.

One example is the work of Sorce et al. (1985), who put 1-year-old infants on a visual cliff for which the drop-off was neither shallow nor deep but in between (about 30 inches). As a baby crawled toward the "cliff," it would stop and look down. On the other side, as in the Gibson and Walk study, the mother was waiting. Sometimes the mother had been instructed to maintain an expression of fear on her face, while other times the mother looked happy and interested. When infants saw the expression of fear, they refused to crawl any farther. However, most of the infants who saw their mother looking happy checked the "cliff" again and crawled across. When the drop-off was made flat, the infants did not check with the mother before crawling across. This method of nonverbal communication used by infants in determining their behavior is called *social referencing.*

RECENT APPLICATIONS

Gibson and Walk's groundbreaking invention of the visual cliff still exerts a major influence on current studies of human development, perception, emotion, and even mental health. Following is a brief sample.

A study by Berger and Adolph (2003) cited Gibson and Walk's early study in their research on how toddlers analyze the characteristics of tasks involving heights, specifically crossing over a bridge. The researchers coaxed very young toddlers (16 months) to cross bridges of various widths, some with handrails, some without. They found that the children were significantly more likely to cross wider bridges than narrower ones (pretty smart for 16 months!). More interesting, however, was the finding that the toddlers were more likely to attempt the narrow bridge if it had handrails. "Infants who explored the bridge and handrail before stepping onto the bridge and devised alternative bridge-crossing strategies were more likely to cross successfully. [These] results challenge traditional conceptualizations of tools: babies used the handrail as a means for augmenting balance and for carrying out an otherwise impossible goal-directed task" (p. 594).

Another practical application of the visual cliff study looked at the possibilities for using virtual reality to help developmentally disabled children learn to deal safely with the physical environment around them. Strickland (1996) developed a system that incorporates virtual reality to help autistic children safely explore and interact with the world around them. Often these children pose a danger to themselves because their perceptions are either distorted or not fully developed. For example, an autistic child might not perceive drop-offs such as those represented by the visual cliff and would, therefore, be prone to dangerous falls. According to Strickland, however, virtual reality allows us to design custom programs so each individual child may gain valuable motor experience without danger of physical injury.

CONCLUSION

Through the inventiveness of Gibson and Walk, behavioral scientists have been able to study depth perception in a clear and systematic way. Behavioral scientists continue to debate the question of whether this and other perceptual abilities are innate or learned. The truth may lie in a compromise that proposes an interaction between nature and nurture. Perhaps, as various studies have indicated, depth perception is present at birth, but fear of falling and avoidance of danger are learned through experience, after the infant is old enough to crawl around enough to "get into trouble." But whatever the questions are, elegant methodological advances such as the visual cliff allow us to continue to search for answers.

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Campos, J., Hiatt, S., Ramsay, D., Henderson, C., & Svejda, M. (1978). The emergence of fear on the visual cliff. In M. Lewis & L. A. Rosenblum (Eds.), *The development of affect.* New York: Plenum Press.

Sorce, J., Emde, R., Campos, J., & Klinnert, M. (1985). Maternal emotion signaling: Its effect on the visual cliff behavior of 1-year-olds. *Developmental Psychology, 21,* 195–200.

Strickland, D. (1996). A virtual-reality application with autistic children. *Presence: Teleoperators and Virtual Environments, 5*(3), 319–329.