MAPPING THE MIND: THE BRAIN IN ACTION

3.8 Identify different brain-stimulating, -recording, and -imaging techniques.

3.9 Evaluate results demonstrating the brain's localization of function.

Although many questions about the brain remain unanswered, we know far, far more about it today than we did 200, or even 20, years ago. For this, we owe psychologists and related scientists who've developed a host of methods to explore the brain and its functioning a major debt of gratitude. **Listen**

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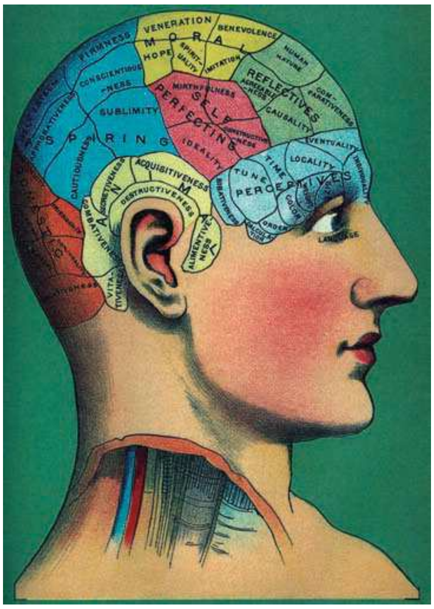


A phrenologist's chart showing where certain psychological traits are supposedly associated with bumps on the skull.

A Tour of Brain-Mapping Methods

Many advances over the past two centuries have enabled scientists to measure brain activity, resulting in a better understanding of how the most complicated organ in the known universe works. But brain research tools weren't always grounded in solid science. Some of the earliest methods were fundamentally flawed, but they paved the way for the newer and improved methods used today.

PHRENOLOGY: AN INCORRECT MAP OF THE MIND. Phrenology—sometimes jokingly called "bumpology" —was one of the first attempts to map mind onto brain. This theory was wildly popular in the 1800s, when phrenologists assessed enlargements of the skull—literally bumps on the head—and attributed various personality and intellectual characteristics to those who sought their "expertise." Phrenologists assumed that bumps on the skull corresponded to brain enlargements, and that these brain enlargements were linked directly to psychological capacities. From the 1820s through the 1840s, thousands of phrenology shops popped up in Europe and North America. Anyone could go to a phrenology parlor to discover his or her psychological makeup. This popular practice was the origin of the familiar expression "having one's head examined."

The founder of phrenology, Viennese physician Franz Joseph Gall (1758–1828), began with some valid assumptions about the brain. He correctly predicted a positive relationship between enlargements in a handful of brain areas and certain traits and abilities, like language. Nevertheless, the up to 37 different traits that phrenologists described—aggressiveness, vanity, friendliness, and happiness among them—are vastly different from the functions scientists studying the brain today assign to different brain areas. What's more, Gall and others based their hypotheses about the supposed associations between brain areas and personality traits almost entirely on anecdotal observations, which we've learned (see Chapter 1) are often subject to a host of errors.

falsifiability

CAN THE CLAIM BE DISPROVED?

Still, phrenology had one virtue: It was falsifiable. Ironically, this lone asset proved to be its undoing. Eventually, researchers discovered that patients with damage to specific brain areas didn't experience the kinds of psychological deficits the phrenologists predicted. Even more critically, because the shape of the outer surface of the skull doesn't closely match that of the underlying brain, phrenologists weren't even measuring bumps on the brain, as they'd believed. These discoveries ultimately led to the demise of phrenology as an approach.

FACTOID

Mark Twain (1835-1910), often considered America's greatest humorist, once underwent a phrenology reading from Lorenzo Fowler, probably the foremost U.S. proponent of phrenology. Fowler, who was then proponent of Twain's identity, informed Twain that the pattern of bumps on his skull indicated that he had an entirely unremarkable personality with one exception: He lacked a sense of humor. When Twain returned three months later and identified himself, Fowler "discovered" a large skull bump corresponding to humor (Lopez, 2002).

BRAIN DAMAGE: UNDERSTANDING HOW THE BRAIN WORKS BY SEEING HOW IT DOESN'T. New methods quickly arose to fill the void left by phrenology. Foremost among them were methods of studying psychological functioning following damage to specific brain regions. We've already mentioned the pioneering work of Broca and others that linked specific areas of the cerebral cortex to specific functions. More recently, scientists have created lesions, that is, areas of damage, in experimental animals using stereotaxic methods, techniques that permit them to pinpoint the location of specific brain areas using coordinates, much like those navigators use on a map. Today, *neuropsychologists* rely on sophisticated psychological tests, like measures of reasoning, attention, and verbal and spatial ability, to infer the location of brain dysfunction in human patients. Neuropsychological tests, which require specialized training to administer, score, and interpret, include laboratory, computerized, and paper-and-pencil measures designed to assess patients' cognitive strengths and weaknesses (Lezak, Howieson, & Loring, 2004).

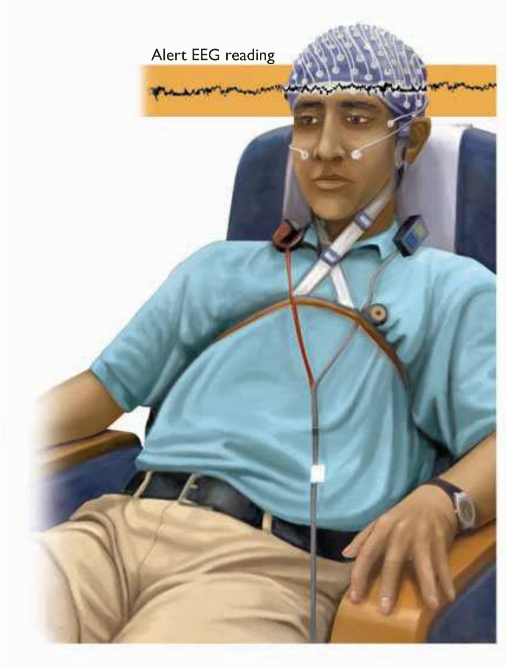


FIGURE 3.19 Electroencephalograph (EEG). An EEG reading during wakefulness.

ELECTRICAL STIMULATION AND RECORDING OF NERVOUS SYSTEM ACTIVITY. Although early studies of function following brain damage provided valuable insights into which brain areas are responsible for which behaviors, many questions remained. Researchers soon discovered that stimulating parts of the human motor cortex in patients undergoing brain surgery produced extremely specific movements (Penfield, 1958). This finding, among others, led to the hypothesis that neurons use electrical activity to send information. But to test that hypothesis, scientists needed to record electrical activity from the nervous system.

To that end, Hans Berger (1929) developed the **electroencephalograph (EEG)**, a device—still widely used today—that measures electrical activity generated by the brain (see **FIGURE 3.19**). Patterns and sequences in the EEG allow scientists to infer whether a person is awake or asleep, dreaming or not, and to tell which regions of the brain are active during specific tasks. To obtain an EEG record, researchers record electrical activity from multiple electrodes placed on the scalp's surface.

Because the EEG is noninvasive (that is, it doesn't require us to penetrate bodily tissue), scientists frequently use it in both animal and human studies. EEGs can detect very rapid changes in the electrical activity of the brain occurring in the range of milliseconds (one-thousandths of seconds). Even today, researchers use EEGs to study brain activity in the brains of individuals with schizophrenia, epilepsy, and other psychiatric and neurological disorders as well as those without disorders. But EEGs have a few disadvantages. Because they show averaged neural activity that reaches the surface of the scalp, they tell us little, if anything, about what's happening inside neurons. In this respect, interpreting EEGs is a bit like trying to understand the mental states of individual people in a stadium with 100,000 football fans by measuring how often they cheer, clap, or boo in response to plays on the field; we'll certainly do better than chance, but we'll make lots of mistakes too. EEGs also aren't especially good for determining exactly where in the brain the activity is occurring.

BRAIN SCANS. Although electrical recording and stimulation provided the initial routes for mapping mind functions onto brain areas, a virtual revolution in brain research occurred with the advent of brain scans, or *neuroimaging*. As a group, these imaging methods enable us to peer inside the brain's structure (that is, its appearance), its function (that is, its activity), and sometimes both.

CT Scans and MRI Images. In the mid-1970s, independent teams of researchers developed **computed tomography (CT)** and **magnetic resonance imaging (MRI)**, both of which allow us to visualize the brain's structure (Hounsfield, 1973; Lauterbur, 1973). The CT scan is a three-dimensional reconstruction of multiple X-rays taken through a part of the body, such as the brain. As a result, it shows far more detail than an individual X-ray. The MRI shows structural detail using a different principle. The MRI scanner measures the release of energy from water in biological tissues following exposure to a magnetic field. MRI images are superior to CT scans for detecting soft tissues, such as brain tumors.

PET. CT and MRI scans show only the brain's structure, not its activity. Therefore, neuroscientists interested in thought and emotion typically turn to *functional imaging* techniques like **positron emission tomography (PET)**, which measures changes in the brain's

FICTOID

MYTH: Research using brain imaging is more "scientific" than other psychological research.

REALITY: Brain imaging research can be extremely useful but, like all research, can be misused and abused. Yet because it seems scientific, we can be more persuaded by brain imaging research than we should be. In fact, studies show that undergraduates are more impressed by claims accompanied by brain imaging findings than research that isn't, even when the claims are bogus (McCabe & Castel, 2008; Weisberg et al., 2008).

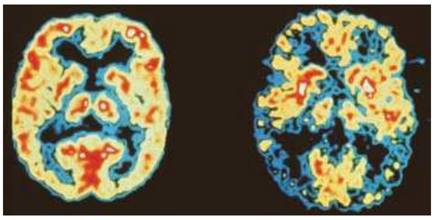
electroencephalograph (EEG)
recording of brain's electrical activity at the surface of the skull

computed tomography (CT)
a scanning technique using multiple X-rays to construct three-dimensional images

magnetic resonance imaging (MRI)
technique that uses magnetic fields to indirectly visualize brain structure

positron emission tomography (PET)
imaging technique that measures consumption of glucose-like molecules, yielding a picture of neural activity in different regions of the brain

Magnetic resonance imaging (MRI) is a noninvasive procedure that reveals high-resolution images of soft tissue, such as the brain.



PET scans show more regions displaying low activity (blue and black areas) in an Alzheimer's disease brain (*right*) than a control brain (*left*), whereas the control brain displays more areas showing high activity (red and yellow).

activity in response to stimuli. PET relies on the fact that neurons, like other cells, increase their consumption of glucose (a sugar) when they're active. We can think of glucose as the brain's gasoline. PET requires the injection of radioactive glucose-like molecules into patients. Although they're radioactive, they're short-lived, so they do little or no harm. The scanner measures where in the brain most of these glucose-like molecules are consumed, allowing neuroscientists to figure out which brain regions are most active during a task. Clinicians can also use PET scans to see how brain activity changes when patients take a medication. Because PET is invasive, researchers continued to work to develop functional imaging methods that wouldn't require injections of radioactive molecules.

fMRI. In 1990, researchers discovered that as neural activity quickens, there's an increase in oxygenated blood in response to heightened demand (Ogawa et al., 1990). The discovery of this response, known as the *blood oxygenation level dependent* (BOLD) response, enabled the development of the **functional MRI (fMRI)**. Because fMRI measures the change in blood oxygen level, it's an indirect correlate of neural activity. Neuroscientists frequently use fMRI to image brain activity in response to specific tasks, like looking at emotional faces or solving math problems (Marsh et al., 2008). The fMRI relies on magnetic fields, as does MRI. fMRI's strength, especially compared with PET, is its ability to provide detailed images of activity in small brain regions and over brief time intervals. Nevertheless, in contrast to PET and some other imaging techniques, fMRI is extremely sensitive to motion, so researchers often have to toss out fMRI data if participants move too much.

correlation vs. causation
CAN WE BE SURE THAT A CAUSES B?

MAGNETIC STIMULATION AND RECORDING. **Transcranial magnetic stimulation (TMS)** applies strong and quickly changing magnetic fields to the skull to create electric fields in the brain. Depending on the level of stimulation, TMS can either enhance or interrupt brain function in a specific region. TMS offers useful insights regarding which brain areas are involved in different psychological processes. For example, if TMS interrupts functioning in the temporal lobe and the subject displays (temporary!) language impairment as a result, we can conclude that the temporal lobe is important for language processing. Because it allows us to manipulate brain areas directly, TMS is the only noninvasive brain imaging technique that allows us to infer causation—all other techniques can only *correlate* brain activation with psychological processing. Some reports suggest that TMS provides relief for depression and may decrease auditory hallucinations, that is, the hearing of sounds, typically voices (Saba, Schurhoff, & Leboyer, 2006). *Repetitive TMS* (rTMS) also shows promise as a treatment for depression (Rachid & Bertschy, 2006).

A final imaging technique is **magnetoencephalography (MEG)**, which detects electrical activity in the brain by measuring tiny magnetic fields (Vrba & Robinson, 2001). In this way, MEG reveals patterns of magnetic fields on the skull's surface, thereby revealing which brain areas are becoming active in response to stimuli. MEG's strength is its ability to track brain changes over extremely small time intervals. In contrast to PET and fMRI scans, which measure activity changes second by second, MEG measures activity changes millisecond by millisecond.

How to Interpret—and Misinterpret—Brain Scans. PET, fMRI, and other functional brain imaging techniques have taught us a great deal about how the brain's activity changes in response to different stimuli. They've also helped scientists to uncover deficits in the brain functioning of people with certain psychiatric disorders. For example, they've revealed that schizophrenia, a severe disorder of thought and emotion marked by a loss of contact with reality, is often associated with underactivity of the frontal lobes (Andreasen et al., 1997; see Chapter 15).

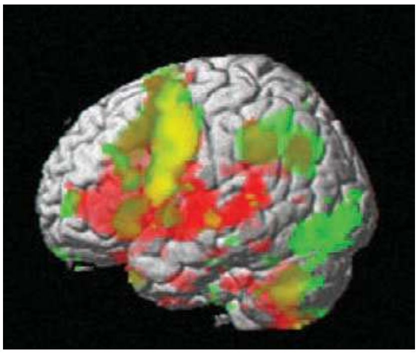
Yet it's extremely easy to misinterpret brain scans, largely because many laypersons and even newspaper reporters hold misunderstandings of how they work (Racine, BarIlan, & Illes, 2006). For one thing, many people assume that functional brain images, like the mul-

functional MRI (fMRI)
technique that uses magnetic fields to visualize brain activity using the BOLD response

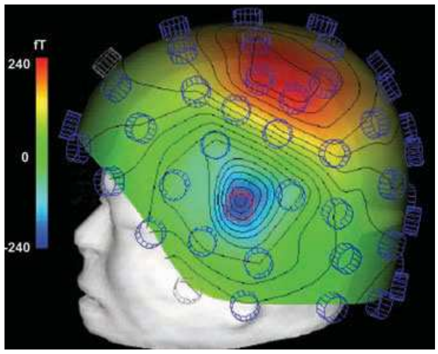
transcranial magnetic stimulation (TMS)
technique that applies strong and quickly changing magnetic fields to the surface of the skull that can either enhance or interrupt brain function

magnetoencephalography (MEG)
technique that measures brain activity by detecting tiny magnetic fields generated by the brain

ticolor images generated by PET and fMRI scans, are like photographs of the brain in action (Roskies, 2007). They aren't. In most cases, these images are produced by subtracting brain activity on a "control" task from brain activity on an "experimental" task, which is of primary interest to the researchers. For example, if researchers wanted to find out how people with clinical depression process sad faces, they could subtract the brain's activity following neutral faces from its activity following sad faces. So although we're seeing one image, it's actually one image subtracted from another. Moreover, the pretty colors in these images are arbitrary and superimposed by researchers. They don't correspond directly to the brain's activity (Shermer, 2008). Making matters more complicated, when a brain area "lights up" on a brain scan, we know only that neurons in that region are becoming more active. They might actually be *inhibiting* other neurons rather than exciting them.



An fMRI of the brain showing areas that were active when subjects remembered something they saw (*green*), something they heard (*red*), or both (*yellow*). *(Source:* M. Kirschen/Stanford University)



An example of magnetoencephalography (MEG) illustrating the presence of magnetic fields on the surface of the cerebral cortex. *(Source:* Arye Nehorai/Washington University, St. Louis)

Another complexity is introduced by the fact that when researchers conduct the calculations that go into brain scans, they're typically comparing the activity of hundreds of brain areas across neutral versus experimental tasks (Vul et al., 2009). As a result, there's a risk of chance findings—those that won't replicate in later studies. To make this point, one mischievous team of researchers (Bennett et al., 2009) placed a dead salmon in a brain scanner, flashed it photographs of people in social situations, and asked the salmon to guess which emotions the people were experiencing (no, we're not making this up). Remarkably, the investigators "found" an area in the salmon's brain that became active in response to the task. In reality, of course, this activation was just a statistical artifact, a result of the fact that they'd computed so many analyses that a few were likely to be statistically significant (see Chapter 2) by chance. This finding is a needed reminder that we should view many brain imaging findings with a bit of caution until other investigators have replicated them.

replicability

CAN THE RESULTS BE DUPLICATED IN OTHER STUDIES?

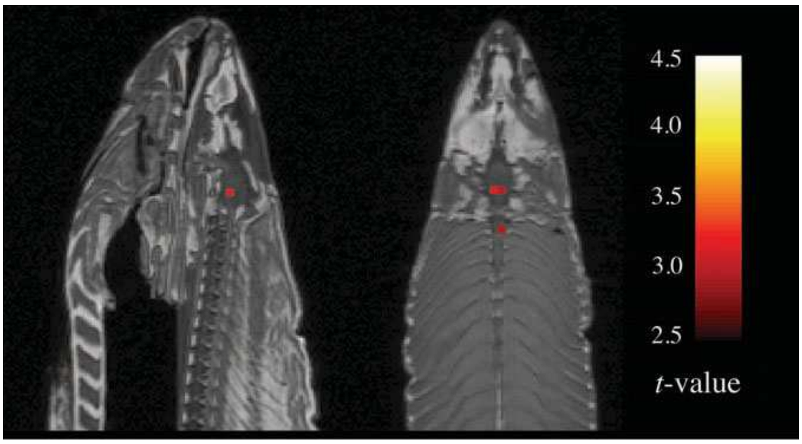
How Much of Our Brain Do We Use?

Despite having so much information available today regarding the relationship between brain and behavior, scores of misconceptions about the brain abound. One widely held myth is that most of us use only 10 percent of our brain (Beyerstein, 1999). What could we do if we could access the other 90 percent? Would we find the cure for cancer, acquire great wealth, or write our own psychology textbook?

The 10-percent myth gained its toehold at around the same time as phrenology, in the late 1800s. William James (1842–1910), one of the fathers of psychology (see Chapter 1), wrote that most people fulfill only a small percent of their intellectual potential. Some people misconstrued James to mean that we only use about 10 percent of our brain. As the 10-percent myth was repeated, it acquired the status of an urban legend (see Chapter 13).

Early difficulties in identifying which brain regions controlled which functions probably reinforced this misconception. In 1929, Karl Lashley showed that there was no single memory area in the brain (see Chapter 7). He made multiple knife cuts in the brains of rats and tested them on mazes. He found that no specific cortical area was more critical to maze learning than any other. Lashley's results were ripe for misinterpretation

A "Fishy" Result? Researchers (Bennett et al., 2009) showed that even a dead salmon can seem to be responding to stimuli—see the red regions of "brain activation"—using standard imaging techniques (to see how, read the text). This finding doesn't show that brain imaging techniques aren't useful, of course, but they show that positive findings can sometimes arise by chance.



Contrary to popular psychology claims that we use only 10% of our brain, we use most or even all of our brain capacity virtually all of the time.

as evidence for "silent" areas in the cerebral cortex—those that presumably did nothing. In fact, we know today that these supposedly silent areas comprise much of the association cortex, which as we've already learned serves invaluable functions. Given how appealing the idea of tapping into our full potential is, it's no wonder that scores of pop psychology writers and so-called self-improvement experts have assured us they know how to harness our brain's full potential. Some authors of self-help books who were particularly fond of the 10-percent myth liberally misquoted scientists as saying that 90 percent of the brain isn't doing anything. Believers in psychic phenomena have even spun the fanciful story that because scientists don't know what 90 percent of the brain is doing, it must be serving a psychic purpose, like extrasensory perception (ESP) (Clark, 1997).

Today, we now know enough about the brain that we can safely conclude that every brain region has a function. Specialists in clinical neurology and neuropsychology, who deal with the effects of brain damage, have shown that losses of even small areas of certain parts of the brain can cause devastating, often permanent, losses of function (Sacks, 1985). Even when brain damage doesn't cause severe deficits, it produces some change in behavior, however subtle.

The fatal blow against the 10-percent myth, however, finally came from neuroimaging and brain stimulation studies. No one's ever discovered any perpetually silent areas, nor is it the case that 90 percent of the brain produces nothing of psychological interest when stimulated. All brain areas become active on brain scans at one time or another as we think, feel, and perceive (Beyerstein, 1999).

Which Parts of Our Brain Do We Use for What?

Scientists refer to *localization of function* when they identify brain areas that are active during a specific psychological task over and above a baseline rate of activity. We should be careful not to overemphasize localization of function, though, and we need to be especially cautious in our interpretations of neuroimaging results. William Uttal (2001) warned that researchers are too quick to assign narrowly defined functions to specific brain regions. He pointed out that we can't always dissect higher brain functions into narrower components. Take visual perception, for example: Can we divide it into neat and tidy subcomponents dealing with color, form, and motion, as the cortical localization of functions might imply, or is visual perception a unified experience supported by multiple regions? It's almost certainly the latter.

Regrettably, much of the popular media hasn't taken Uttal's useful cautions to heart. On a virtually weekly basis, we'll encounter news headlines like "Alcoholism Center in Brain Located" or "Brain Basis of Jealousy Found" (Cacioppo et al., 2003). To take another example, in the late 1990s and as recently as 2009, some newspapers announced the discovery of a "God spot" in the brain when scientists found that certain areas of the frontal lobes become active when individuals think of God. Yet most brain imaging research shows that religious experiences activate a wide variety of brain areas, not just one (Beauregard & Paquette, 2006). As Uttal reminds us, few if any complex psychological functions are likely to be confined to a single brain area. **Simulate**

Simulate the Hemispheric Experiment on **mypsychlab.com**

Just as multiple brain regions contribute to each psychological function, individual brain areas contribute to multiple psychological functions. Broca's area, well known to play a role in speech, also becomes active when we notice that a musical note is off key (Limb, 2006). There's enhanced activity in the amygdala and other limbic regions when we listen to inspiring music, even though these regions aren't traditionally known as "musical areas" (Blood & Zatorre, 2001). The rule of thumb is that each brain region participates in many functions—some expected, some unexpected—so coordination across multiple brain regions contributes to each function.

Some news sources refer to the possibility of a God spot in the brain as identified by imaging research. Yet most scientists, like Dr. Andrew Newberg (shown here), argue that the localization of religion and other complex cognitive capacities to one or two brain regions is extremely unlikely.

Which Side of Our Brain Do We Use for What?

As we've learned, the cerebral cortex consists of two hemispheres, which are connected largely by the corpus callosum. Although they work together closely to coordinate functions, each hemisphere serves different functions. Many functions rely on one cerebral hemisphere more than the other; scientists call this phenomenon **lateralization** (see **TABLE 3.3**). Many lateralized functions concern specific language and verbal skills.

Roger Sperry (1974) won the Nobel Prize for showing that the two hemispheres serve different functions, such as different levels of language ability. His remarkable studies examined patients who underwent **split-brain surgery** because their doctors couldn't control their epilepsy with medication. In this exceedingly rare operation, neurosurgeons separate a patient's hemispheres by severing the corpus callosum. Split-brain surgery typically offers relief from seizures, and patients behave normally under most conditions.

Nevertheless, carefully designed studies reveal surprising deficits in split brain patients. Specifically, they experience a bizarre fragmenting of mental functions that we normally experience as integrated. Putting it a bit differently, the two hemispheres of split-brain subjects display somewhat different abilities, even though these individuals experience themselves as unified persons (Gazzaniga, 2000; Zaidel, 1994).

Here's what Sperry and his colleagues did. They presented stimuli, such as written words, to either patients' right or left *visual field*. The right visual field is the right half of information entering each eye, and the left visual field is the left half of information entering each eye. To understand why researchers present stimuli to only one visual field, we need to know that in normal brains most visual information from either the left or right visual field ends up on the opposite side of the visual cortex. The brain's design also results in crossing over for motor control: The left hemisphere controls the right hand, the right hemisphere controls the left hand.

Because corpus callosum transfers information between the two hemispheres, cutting it prevents most visual information in each visual field from reaching the visual cortex on the same side. As a consequence, we often see a stunning separation of functions. In one extreme case, a split-brain subject complained that his left hand wouldn't cooperate with his right hand. His left hand misbehaved frequently; it turned off TV shows while he was in the middle of watching them and frequently hit family members against his will (Joseph, 1988).

Split-brain subjects often experience difficulties integrating information presented to separate hemispheres, but find a way to explain away or make sense of their bewildering behaviors. In one study, researchers flashed a chicken claw to a split-brain patient's left hemisphere and a snow scene to his right hemisphere (see **FIGURE 3.20**). When asked to match what he saw with a set of choices, he pointed to a shovel with his left hand (controlled by his right hemisphere) but said "chicken" (because speech is controlled by his left hemisphere). When asked to explain these actions, he said, "I saw a claw and I picked the chicken, and you have to clean out the chicken shed with a shovel."

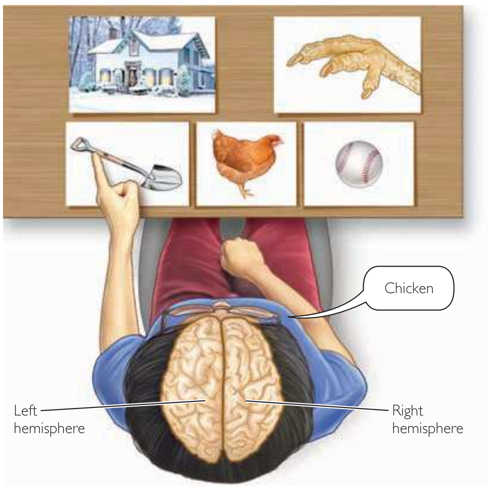


FIGURE 3.20 Split-Brain Subject. This woman's right hemisphere recognizes the snow scene and leads her to point to the shovel, but her left hemisphere recognizes the claw and indicates verbally that the chicken is the matching object.

TABLE 3.3 Lateralized Functions

LEFT HEMISPHERE
Fine-tuned language skills
• Speech comprehension
• Speech production
• Phonology
• Syntax
• Reading
• Writing
Actions
• Making facial expressions
• Motion detection
RIGHT HEMISPHERE
Coarse language skills
• Simple speech
• Simple writing
• Tone of voice
Visuospatial skills
• Perceptual grouping
• Face perception

(*Source:* Adapted from Gazzaniga, 2000)

? This man has suffered a stroke that affected the left side of his face. On what side of his brain did his stroke probably occur, and why? (See answer upside down on bottom of page.)

lateralization
cognitive function that relies more on one side of the brain than the other

split-brain surgery
procedure that involves severing the corpus callosum to reduce the spread of epileptic seizures

Answer: Right side, because nerves cross over from one side of the brain to the other side of the body.

psychomythology

ARE THERE LEFT-BRAINED VERSUS RIGHT-BRAINED PERSONS?

Despite the great scientific contribution of split-brain studies, the popular notion that normal people are either "left-brained" or "right-brained" is a misconception. According to this myth, left-brained people are scholarly, logical, and analytical, and right-brained people are artistic, creative, and emotional. One Internet blogger tried to explain the differences between people's political beliefs in terms of the left–right brain distinction; conservatives, he claimed, tend to be left-brained and liberals right-brained (Block, 2006). Yet these claims are vast oversimplifications of a small nugget of truth, because research demonstrates that we use both sides of our brain in a complementary way (Corballis, 1999; Hines, 1987). Furthermore, the corpus callosum and other interconnections ensure that both hemispheres are in continual communication.

We can trace the myth of exaggerated left brain versus right brain differences to misinterpretations of accurate science. Self-help books incorporating the topic have flourished. Robert E. Ornstein was among those to promote the idea of using different ways to tap into

"Roger doesn't use the left side of his brain or the right side. He just uses the middle."

Still, we must guard against taking lateralization of function to an extreme. Remarkably, it's possible to live with only half a brain, that is, only one hemisphere. Indeed, a number of people have survived operations to remove one hemisphere to spare the brain from serious disease. Their outlook is best when surgeons perform the operation in childhood, which gives the remaining hemisphere a better chance to assume the functions of the missing hemisphere (Kenneally, 2006). The fact that many children who undergo this procedure develop almost normally suggests that functional localization isn't a foregone conclusion.

DIAGNOSING YOUR BRAIN ORIENTATION

evaluating CLAIMS

Many online quizzes claim to identify you as either "left-brained" or "right-brained" based on which direction you see an image move, whether you can find an image hidden in an ambiguous photo, or your answers to a series of multiple-choice questions. Other websites and books claim to help you improve your brain's nondominant side. Let's evaluate some of these claims, which are modeled after actual tests and products related to brain lateralization.

"*Left-brained people* are more likely to focus on details and logic and to follow rules and schedules. They do well in math and science. *Right-brained people* are more likely to be deep thinkers or dreamers, and to act more spontaneously. They excel in the social sciences and the arts."
The ad implies incorrectly that some people are left-brained and others right-brained, when in fact the left and right hemispheres differ only in emphasis.

"This *quick test* can help you determine your dominant side in just a few seconds."
This extraordinary claim isn't supported by extraordinary evidence. Furthermore, what would we need to know about this test to determine if it's valid?

"Use these exercises to improve the information flow between your left and right brain and *improve your performance* on spelling tests and listening comprehension."
There's no research to support the claim that these exercises will improve your academic performance.

Answers are located at the end of the text.