CHAPTER 2

Wiring the Young Brain

"Before you become too entranced with gorgeous gadgets and mesmerizing video displays, let me remind you that information is not knowledge, knowledge is not wisdom, and wisdom is not foresight. Each grows out of the other, and we need them all."

—Arthur C. Clarke (1917–2008), British Science Fiction Author, Inventor, and Futurist

JUST A MINUTE! THE TITLE OF this book mentions the "rewired brain." Yet this chapter title starts off with "wiring the young brain." Am I using these terms interchangeably? Absolutely not and allow me to explain. Nature has prewired the infant brain to perform certain tasks that evolution has found to be helpful for the survival of our species. These cerebral regions begin their work as soon as they have a sufficient amount of neural connections and networks to act purposefully and specifically to process and store important information and skills. Some of this wiring starts in the womb. After birth, nurturing exposes infants to the trove of sensory data present in their particular surroundings that the brain uses to boost and consolidate these networks. This process is the "wiring." My premise is that the infants, toddlers, and young children of today are coming into an environment that is very different from the early environments that led to the original genetic wiring many thousands of years ago. More important, the forces in this environment, driven largely by revolutionary changes in technology, are actually rewiring the primal neural circuits.

Our society seems to encourage early access to technology by our youth and, thus, is inadvertently promoting this rewiring.

No doubt, some of this support is due to parental concerns over their child's safety because of incidents of violence in schools. For better and for worse, the rewiring is producing a generation of students whose view of the world and their place in it will be quite different from that of their predecessors, and deserves the immediate attention of parents and teachers. My explanations, supported by emerging research, follow. There is one caution: After reading this chapter, the reader may conclude that I am focusing just on the negative impact of technology on our youth. As we will see, some of the impact is undesirable, especially as it applies to infants and toddlers. However, regardless of the impact, I am aware that technology is a reality of today's environment that is not going to disappear. So, we need to recognize its impact on young children, decide how we are going to deal with it, and explore what we need to do in the teaching and learning process to accommodate this reality for the common good. Before we can understand how technology is rewiring the young human brain, we need to explore how it gets wired in the first place.

GETTING THE BRAIN WIRED

Humans enter this world with a few brain networks already wired in place. These primitive neural grids consolidate during gestation to support the newborn's most basic functions for surviving outside the protective environment of the womb. Among mammals, human babies are the most defenseless at birth, mainly because the growing brain needs to get through the birth canal before it gets too large to make the journey successfully. Even at that, the newborn's brain is only one-third the size of an adult brain but remarkably packs twice as many brain cells—called *neurons*—two hundred billion, which eventually get pruned to about one hundred billion by late adolescence. Consequently, our young remain defenseless and helpless long after birth. They spend more time than any other animal being nurtured by their caregivers. Although this extended rearing period places a substantial long-term responsibility on parents, there are some unique benefits to this evolutionary experience.

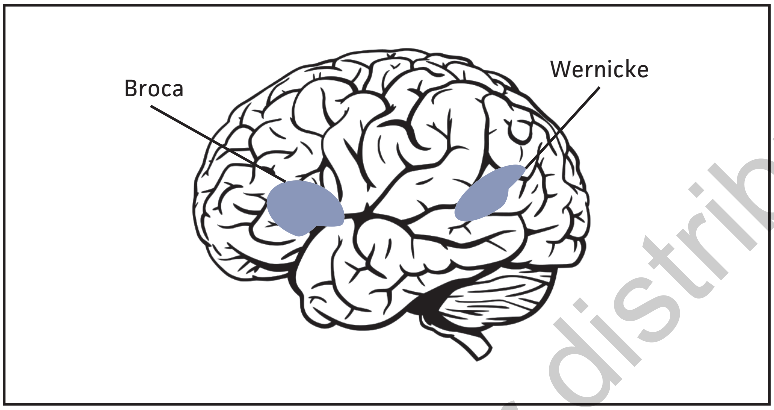
One of those benefits is the brain's responsiveness to external stimuli. As new information continually pours in, the young brain establishes additional neural circuits or extends existing ones in an effort to eventually interpret their significance. This persistent wiring and reshaping of brain circuits caused by environmental input is called *neuroplasticity*. Learning, then, is the epitome of neuroplasticity. The brain is making so many connections that it triples in mass in just the first twelve months after birth. When we learn and remember new information and skills, neural networks are fired up and connected in such a way as to preserve that learning so we can recall it when needed. Contrary to earlier beliefs, this dynamic process continues for a lifetime and becomes increasingly important as we age because it is the best known defense at present to ward off the debilitating effects of age-related dementia. The old adage “Use it or lose it” is especially appropriate in this scenario. As we age, we should exercise not only our body, but our brain as well, such as learning to speak a new language, play a musical instrument, or travel for new adventures.

But I digress. Let’s get back to the young brain. As I mentioned earlier, several prewired areas are already in place at birth as a result of genetic influences. For example, a large portion of the back part of our brain, called the *visual cortex*, is reserved almost exclusively for processing visual input. That is most likely because so much of the information we get from our environment involves the sense of sight. Being able to see predators, prey, friends, and foes clearly and with good depth perception largely contributed to the survival of our species.

Wiring for Spoken Language

Other brain areas are particularly responsive to spoken language. They include one section behind the left temple, referred to as *Broca’s area*, and another just behind the back of the left ear, called *Wernicke’s area* (see Figure 2.1). The former region is named after French physician Paul Broca, who in the 1860s discovered that damage to this area resulted in the loss of speech, or *aphasia*. Scientists now believe that this area is mainly responsible for language processing and speech production, including processing the vocabulary, syntax, and grammar rules of one’s native language(s). Two decades later, the latter region was discovered by German physician Carl Wernicke, who noticed that not only Broca’s area, but also another part of the brain, was involved in language processing. Damage to this area caused the individual to lose the

FIGURE 2.1 ◆ The diagram shows the location of the two language processing areas of the brain, Broca's and Wernicke's areas.



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ability to comprehend language. These two areas actively communicate with each other whenever we are processing or creating spoken language.

Why do we have specialized cerebral areas for spoken language processing? Like other animals, our primitive ancestors realized that communicating with other members of our species gave us a better chance of survival than not. Early attempts probably started with grunts, groans, and shouts in different pitches and volume. As our brain became more complex, these noises were gradually transformed into more sophisticated and distinct sounds. A part of our brain that processes sounds, called the *auditory cortex*, just behind the ears, got better at distinguishing slight variations in speech, thereby increasing the bank of individual sounds—called *phonemes*—needed to create more words. Eventually we were able to connect phonemes thereby creating words to describe objects and actions, resulting in a primitive spoken language.

All typically developing children learn their native language easily and without explicit instruction. What is astonishing is that gene expression for spoken language is so strong, despite the complexity of human languages, that at thirty-three to forty-one weeks of gestation, the fetus can learn and respond differently to its mother's voice than to others' (Kisilevsky et al., 2009). Toddlers learn their native tongue by listening closely to their caregivers' language and separating repetitive sounds from background noise. Caregivers, meanwhile, do their part by speaking slowly in lilting tones and exaggerating their pronunciation of phonemes. This singsong enunciation, called *parentese*, is found in all cultures and helps the toddler detect and discriminate the sounds of language from other auditory signals and background noise. Furthermore, toddlers can learn one, two, or even three languages simultaneously. This occurs because each language has its own prosody, that unique pattern of hard and soft sounds, changes in tone, shifts in pacing, and stresses in pronunciation. Language areas of the young brain can cerebrally distinguish and consolidate each language by its prosody. However, because this is such a labor-intensive process, it can usually occur only at a very young age when the brain has all those extra neurons available for wiring new connections.

By the age of three, children learn the rules governing the pronunciation and word order of their language, as well as master the practical rules governing how to use language to communicate with others. During this time, the brain is creating and wiring language circuits with amazing speed and accuracy. It tags words that the child uses often as components of the *active vocabulary*. Other words that the child comprehends but does not use comprise the *passive vocabulary*. When these children get to kindergarten, they already have an active vocabulary of up to three thousand words and a passive vocabulary of up to seven thousand words, depending on the level of literacy in their home.

Impact of Technology on Spatial and Language Development

Whatever stimuli children experience during the first three years of their lives will profoundly influence brain development. Enter technology. Past surveys have indicated that by the age of five months, about 40 percent of infants are watching some sort of video. By the age of two years, the number increases to 90 percent (Hill, 2013). Given the vast proliferation of video screens since the last surveys were done, it is reasonable to assume that these percentages have grown. Images on media differ greatly from the images they receive from their parents. Visual processing regions are trying to make sense of the children's world. It is a three dimensional world, but the screen exists in two dimensions. Images on the screen appear and disappear, and there is no way for the toddlers to grasp objects they see in motion. As a result, the toddlers have difficulty with spatial relationships, and their brain is incapable of making sense out of the inexplicable two dimensional pictures in a three dimensional environment.

Implication: *Television watching by infants and toddlers may hinder their spatial skill development.*

Language development gets confused as well. Media do not speak parentese, nor is the pace of speech slow enough for the auditory processing system to distinguish phonemes from background noise. Moreover, when toddlers look at a parent speaking parentese, they watch the movement and shape of the lips and position of the tongue as the parent forms different sounds. This information will help them when they try to reproduce these sounds later to form words. They also listen to tone of voice and watch body language and facial expressions to get important clues about the meaning of words and phrases. There is little or no such deliberate and measured feedback from media. Furthermore, having the television on in the background, even if the toddler is not watching it, seems to be enough to delay language development. Studies show that a parent normally speaks about 940 words per hour when a toddler is around. When the television is on, that number falls dramatically by 770 to just 170 words per hour. Fewer words mean less vocabulary development and less language learning. And the notion touted by educational entrepreneurs that watching television builds vocabulary does not have any support in research. In fact, recent studies show that watching even so-called educational programs on television does not improve a toddler's vocabulary (Alloway, Williams, Jones, & Cochrane, 2014) and, in fact, may delay typical cognitive development (Stockdale et al., 2022).

Implication: *Television watching by infants and toddlers may delay their development of language.*

It is no surprise, then, that evidence continues to mount indicating habitual television and video viewing for long hours is delaying language development in young children (e.g., Courage & Howe, 2010; Duch et al., 2013; Canadian Pediatric Society, 2017). As a result of this research, the American Academy of Pediatrics (2015) strongly recommends that parents and caregivers eliminate media exposure completely for children under the age of two. This will be no easy task, because parents see problems to restricting or eliminating time spent watching television or other media. A study of one hundred eighty children and their parents revealed three significant problems: (1) limiting children's screen-watching time will cause conflict in the home because of children's anger at their parents' new rules and increased bickering between siblings; (2) replacing screen time as entertainment takes time away from parents; and (3) limiting screen time reduces the opportunities for free babysitting, entertainment, and educational programming (Evans, Jordan, & Horner, 2011).

Parents are often reluctant to limit the amount of television young children watch, because that may create friction and discipline problems in the family.

THE ADDICTION OF ELECTRONIC ENGAGEMENT

Toddlers from one to four years of age are like sponges, sopping up information from their environment at an enormous speed. During this stage of their development, the brain is making new connections at the astonishing rate of tens of thousands per second. In earlier times, children got most of their information from their parents or caregivers. Engaging with toys produced little additional information because toys were generally passive objects that did not add much to the child's information base.

Implication: *We can assume that children who spend their early years in front of screens will eventually have adult brains hardwired to process information at a frantic pace.*

Today, the situation is the reverse: Toddlers engage with their electronic toys, and the toys respond accordingly. It is an effort for the parents to draw the child's attention away from the toys if they want a conversation. Consequently, at a very early and cerebrally impressionable age, youngsters are learning that their electronic toys are much more exciting and stimulating than conversing with mom, dad, or siblings. The draw of the toys is so appealing that the young brain develops a genuine addiction to engaging with technology rather than with humans. In other words, at a time when a young brain should be recognizing the value of developing social skills to interact successfully with other humans, it is instead developing the fine finger motor skills needed to successfully manipulate the electronics in its environment.

Moreover, around the age of three years, seldom used or unused neurons start to get pruned so that the active neurons have more space to grow new connections. This process, called *apoptosis*, is similar to farmers pulling up weaker seedlings to allow more space and nourishment for the healthier ones. We can reasonably assume, then, that the way children use their brains at a young age is going to affect the pruning process. In other words, children who spend their early years in front of screens will eventually have adult brains that are hardwired to process information at a frantic pace.

There is no escape. Technology is omnipresent. The average amount of screen time for 8 to 12 year-olds increased from 4 hours 44 minutes in 2019 to 5 hours 33 minutes in 2021, a 17 percent increase in just two years. For 13 to 18 year-olds, screen time increased from 7 hours 22 minutes in 2019 to 8 hours 39 minutes in 2021, also a 17 percent increase (Rideout et al., 2021).

The Distress of Disconnecting From TechnologySeveral studies show that disconnecting from technology can cause distress and anxiety in students. The International Center for Media & the Public Agenda conducted a study in which they asked 200students from the University of Maryland, College Park, to abstain from using all media for 24 hours (Wordpress, 2021). After the 24-hour period, the students were asked to write on a private blog about their successes and any failures during their period of abstinence. In total, the 200 students wrote more than 110,000 words. Their comments were very revealing about how deeply they have become addicted to technology.

One student wrote, "I clearly am addicted and the dependency is sickening." Another described how he started the day feeling fine, but noticed that his mood began changing around noon. He felt isolated and lonely, like a person on a deserted island. Loneliness was one of the feelings most often expressed by the students, one noting that the fact that he was not able to communicate with anyone via technology was "almost unbearable." Although these students were without technology for only 24 hours, many of the feelings they described, such as loneliness, moodiness, and anxiety, are the same as those experienced by people who are actually addicted to technology and deprived of it.

Students often use the word addicted *to describe their dependence on technology.*

Technology Distractions and Student Achievement

The distractions of technology can affect achievement. A study of 118 college students measured the effect of using laptops and cell phones for a non-academic purpose during class on the students' subsequent performance on exams (Glass & Kang, 2019). In a two-section college course, electronic devices were permitted in half the lectures. The students with laptops and cell phones open for non-classroom purposes scored half a letter grade lower on exams compared to the students who did not have or use electronic devices during that class. Other studies have shown that laptops and cell phones not being used directly in instruction can distract students and decrease their in-class learning (e.g., Hall et al., 2020).

This raises some intriguing questions: Are students so easily distracted because their brains are now hardwired for it after a lifetime of rapidly changing and attention-demanding screens? Are there social, cultural, cognitive, and behavioral elements to this fixation that have infiltrated the classroom? If so, what strategies should teachers use at all grade levels to manage their classroom, design their lessons, and carry out effective instruction? For instance, how should they organize the classroom for maximum student engagement? How long can they use direct instruction before students shift their attention to other interests? How do they increase *retention* of learning with so many potential technological distractions in the classroom? How does social media affect classroom climate, and can teachers use it to enhance learning? These are some of the major questions addressed in the following chapters. First, let us summarize the concept of wired to rewired.

SUMMARY: WIRED TO REWIRED BRAIN

As our species evolved, certain activities that persistently proved highly favorable for survival eventually altered our genetic framework. Encoding spoken language, visual discrimination, spatial skills, and social interactions as specialized functions with prewired circuits ensured that these capabilities were passed on to future generations. The genetic enhancements caused humankind not only to flourish, but to become the dominant species on the planet, even though we are not the largest or the fastest. Over the millennia, not much in the environment significantly affected our genetic composition. Gamma rays and chemicals in the environment could cause a mutation in an individual's DNA, but that was unlikely to permanently affect a large population over time. Consequently, as far as we know, the brain regions that were prewired in ancient times are similarly prewired in newborns today.

Along comes twenty-first–century technology. Unlike twentieth-century technology that developed relatively slowly, new electronic devices are appearing and evolving at breakneck speed. Even before one has mastered the functions of one smartphone, a newer version with more options emerges. Although this ever-changing nature of technology can be a challenge for the adult brain, the young brain adapts effortlessly, thanks to neuroplasticity. And therein lies the source for rewiring.

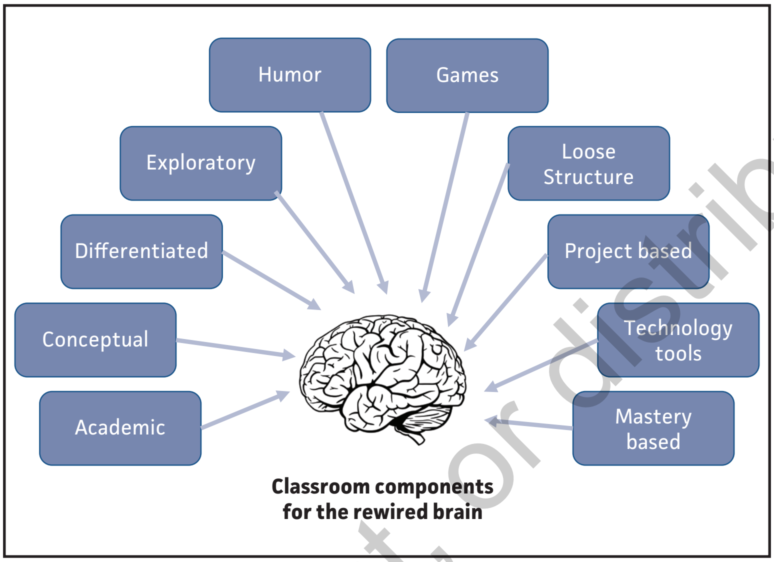
Just five hours of training was enough to rewire the brains of adults to better search the Internet

We should point out that this rewiring is not limited to young brains. A classic experiment carried out with young adults showed how easily rewiring can occur. The study involved one group of adults with extensive computer experience and another group with no computer experience (Small & Vorgan, 2008). Researchers used a *functional magnetic resonance imaging (fMRI)* scanner while both groups read pages from a book, and noted that all participants used the same neural pathways to accomplish this task. However, when the researchers asked them to do a Google search, the scans were very different. Experienced computer users activated pathways in the left frontal lobe, while nonusers had no such activation. After receiving one hour of instruction for five days on how to use search engines, the nonusers were scanned again. The results showed that they were now activating the same left frontal lobe pathways as the experienced users. Their brains had rewired after just five hour of training. Other studies have also shown this amazing power of brain plasticity (e.g., Bennett et al., 2018). Teachers who understand this power can lead students to remarkable achievement, if they design their classrooms with this brain in mind.

WHAT KIND OF CLASSROOM WILL ENGAGE THE REWIRED BRAIN?

Having explored how technology is rewiring the brain, we should now consider two relevant questions: (1) What type of classroom environment would be most welcoming for these digital native students? (2) What components of classroom management and instructional strategies are most likely to keep this brain engaged and motivated to learn? The following chapters will reveal the answers to these questions in

FIGURE 2.2 • The illustration shows the components of a classroom environment compatible with the rewired brain.



detail. Nevertheless, it is worth mentioning them now to prepare the reader's mind-set for what may be a significant revamping of present-day classroom practices.

As Figure 2.2 illustrates, the environment is student centered and takes advantage of the learning preferences of the rewired brain (Gutierrez, 2013). Here is a brief explanation of each of these components.

An Academic Component

Teacher questions about content and skills are mostly of the higher-order variety, requiring analysis and creativity to answer them. The teacher's main task here is to lead the students to find the answers for themselves, promoting *self-regulation* of their learning.

A Conceptual Component

Class discussions, either as a whole group or in small groups, center on basic concepts and not on the memorization of isolated facts. Physical and virtual manipulatives appear when they add to deeper understanding of course content.

A Differentiation Component

Although all students are working toward the same learning objectives, the levels and methods of learning can vary among students, depending on their background knowledge, interests, and learning profiles.

An Exploratory Component

The teacher uses direct instruction when necessary, but more often the students are asked to research content on their own and to view appropriate videos that reinforce concepts. The teacher encourages students to recommend sources to each other.

Humor Is Included

Because the teacher knows the physiological, psychological, and social benefits of laughter, good-natured humor is always present. Both teacher and students can laugh at their mistakes, while staying in the learning mode. No one can use sarcasm.

Games Are Allowed

Students play educational games that are fun and challenging but always focused on advancing the learning objective. They can compete among themselves or with student teams from other schools via the Internet.

A Loosely Structured Classroom

There is no set seating chart. Students can sit where they like and with whom they choose. Their seating pattern is usually determined by what project the small groups are working on. Students can move their desks when necessary to form groups, and on-task talking is accepted.

Project-Based Learning

Nearly every major curriculum unit has an in-depth project that requires students to delve more deeply into the learning. As they do so, the teacher challenges them to use their creativity and problem-solving skills to apply the new learning to real-world situations. Student academic teaming can be a successful format for these initiatives.

Technology Is an Important Tool

Students use technology tools to improve their learning and achievement. They should explain why using the technology tool is a better advancement of their learning than if they did not have the tool.

Mastery-Based Culture

The aim of the teaching–learning process in the classroom is to help the students reach mastery of their learning goals. The teacher regularly uses formative assessments to measure student progress, emphasizing that mastery requires a growth mind-set and a lot of effort.

This collection is not complete, as one could add other components that encourage student-centered learning experiences for the rewired brain. One important point to note is that the teacher could implement all of these components with very little technology. That point highlights once again the nature of technology as a tool for improving teaching and learning, not an end unto itself.

WHAT'S COMING

Learning rarely occurs unless the brain attends to it. Cerebral attention is actually quite a complicated event, as we shall see in the next chapter. With so many environmental stimuli vying for the students' attention, teachers need to devise strategies that give classroom learning a high priority. Let us see how that can happen.