Chapter 6

BORN LINGUISTS

AGES: BIRTH TO EIGHT YEARS

Complex skills require deep foundations. Babies start to learn language a long time before they are able to speak, preferentially focusing their attention on speech from birth—or even earlier, as hearing becomes functional during the third trimester of pregnancy (see chapter 11). Because babies do not have the motor abilities to express all the knowledge that they have obtained, though, you may not realize how much language they understand at a given age.

Newborn babies already prefer their mother’s voice over other female voices, their native language over other languages, and speech over other sounds that have the same acoustic properties, including speech played backward. They can also detect a variety of vocal cues, including acoustic characteristics, stress patterns, and the rhythms of different languages. From early in life, your infant absorbs the huge amounts of information that will make him an expert in his native language, learning about its cadences, its sounds, the structures of its words, and the grammar of its sentences. As we discussed in chapter 3, most adults instinctively speak to infants in motherese, which is slower than normal language and contains exaggerated versions of consonant and vowel sounds.

Young infants can distinguish and categorize the sounds of all languages of the world, though adults often confuse the sounds of a foreign language. For example, the r and l of English sound the same to Japanese adults, but different to Japanese infants. As they acquire experience with speech, babies begin to specialize in the sounds (called phonemes) of their own language (or languages). By six months of age (for vowels) or ten months (for consonants), babies become better at identifying the phonemes of their native language and worse at identifying the phonemes of other languages. In other words, experience with language shapes
the categories into which babies place sounds, determining which variations in sound characteristics are meaningful (reflecting different phonemes) and which should be ignored (reflecting different speakers or other unimportant variations).

As we would expect, their neural activity reflects this phoneme learning. In older infants, the patterns of electrical signals in the brain recorded from electrodes on the scalp, termed event-related potentials, show that babies distinguish between a pair of sounds from the native language, while failing to distinguish two confusable foreign sounds. In younger infants, event-related potential patterns distinguish both foreign- and native-language sound pairs. This brain specialization is important for future language learning. Babies whose brains discriminate native sounds well (and foreign sounds poorly) at seven and a half months go on to learn language earlier than babies who show the less mature pattern of distinguishing all sounds equally well. The more discriminating babies learn words more quickly, produce more words and more complex sentences at twenty-four months, and produce longer phrases at thirty months than the less discriminating babies. So even though your baby isn’t talking back, he is absorbing the patterns of your talk.

Social interaction is one cue that babies use to determine which sounds they should be learning. Nine-month-old infants who hear a brief tape recording or video of someone speaking a new language do not learn its sounds, but the same
amount of speech from a live person is sufficient to allow the babies to discriminate phonemes in the new language. (Under some circumstances, babies can learn from tape or video, but it takes longer than learning from a live person.) Indeed, certain measures of social interaction with a language teacher (including a parent) predict how well individual infants will remember the sounds of the new language. The preference for social interaction may be part of the reason that autistic children (see chapter 27), who do not interact well with other people (and do not prefer the sounds of motherese), have difficulty learning language.

The timing of speech production is determined by maturation of the brain regions that control movement. Forming understandable sounds requires considerable fine motor control and apparently a lot of practice. Babies first attempt to talk at around two months, when they begin cooing vowels, the least complicated speech sounds to produce. Some consonant sounds follow around five months, when babbling begins. Early babbling sounds the same in all babies, regardless of their native language. Around the end of the first year, babbling starts to include language-specific phonemes.

Responding with a comment or a touch to your baby’s best attempts to communicate seems to encourage continued efforts to improve these skills.

Word learning also starts long before babies can produce words of their own. Six-month-old infants know their own names and will look at a picture of their mommy or daddy when they hear the word. As we discussed in chapter 1, infants can listen to a string of nonsense syllables and determine which of them are most commonly heard together as “words.” They apply this talent to identifying words in normal speech, where words tend to run together without pauses. (To understand this phenomenon, think of the way a foreign language sounds; you can’t guess where one word ends and the next begins.) Later, their brains learn about the regularities of sentence structure that constitute the rules of grammar in their native language. By nine months, familiar and unfamiliar words trigger noticeably different event-related potentials. By the first half of baby’s second year, these potentials are different for words whose meaning
the child does or doesn't understand. Babies' brains also respond differently to made-up words depending on whether or not they obey the rules for which syllable should be stressed in the baby's native language. Stress patterns appear to be another tool that babies use to determine which groups of sounds are words.

In the second year, as children learn more words and become able to say many of them, they become better at distinguishing similar words, like bear and pear. Babies at fourteen months will direct their gaze toward an object even when its name is mispronounced, suggesting that their brain does not yet represent the sounds in known words with complete accuracy. Similarly, at this age, brain activity does not distinguish between familiar words and similar-sounding nonsense words. This changes at around twenty months. The relationship between learning words and learning sounds seems to be bidirectional, so that learning sounds makes it easier to learn words, but learning more words also helps babies improve their ability to distinguish sounds.

Sentences add new layers of complexity to language learning. Again, children can comprehend sentences and grammatical connecting words before they're able to use them in speech. To understand a sentence, your child must know not only the meanings of the individual words (called semantic information) but also how they relate to each other within the sentence (syntactic information). The brain represents these two types of information separately.

For almost everyone (excepting some left-handers), the left hemisphere is dominant for language production. Similar regions in the right hemisphere are responsible for prosody, the tone and rhythm of speech that conveys much of its emotional content. (For example, prosody tells you when someone is being sarcastic or making a joke.) Laterality of language representations seems to be part of the basic pattern of brain connections laid down by genes before sensory experience becomes effective (see chapter 2) because it is apparent by two or three months of age and even occurs in deaf infants. If the dominant speech regions are damaged in childhood, though, especially before the age of five, the other side of the brain can take over their function, leaving language skills relatively normal. If the same damage occurs after puberty, it severely impairs communication abilities.

When we hear something that sounds "wrong," event-potentials in our brains reveal whether we're reacting to syntactic or semantic violations. "The boy walked down the flower" is an example of a semantic violation, while "The boy walk
PRACTICAL TIP: TEACH FOREIGN LANGUAGES EARLY IN LIFE

From the perspective of neuroscience, it's absurd to wait until high school to begin studying a foreign language. By adolescence, students must work much harder to learn a new language, and most of them will never master it completely. If you want your child to speak another language fluently, by far the best approach is to start early in life.

In one study, researchers tested the English grammar proficiency of Chinese or Korean immigrants who had arrived in the U.S. at various ages and stayed at least five years. The test required participants to identify whether there were grammatical errors in sentences like “Tom is reading book in the bathtub” or “The man climbed the ladder up carefully.” The test was simple enough that native English speakers could ace it by the age of six, but the immigrants who began learning English after age seventeen missed many of these simple questions. Only people who came to the U.S. before age seven performed at the level of native speakers. Everyone in the group who arrived at eight to ten years of age did a bit worse, and those who arrived at eleven to fifteen were still less proficient.

Between ages eight and fifteen, researchers found a strong relationship between age of exposure and performance on the test. But in adulthood, individual variability in performance was not connected to age. No matter whether they'd started learning English at eighteen or forty, few adults learned perfectly. (Some later researchers found that language learning in adulthood also declines with age—that is, young adults learn better than older adults—but everyone agrees that young children learn better than older people.)

The take-home message for parents and schools is clear: take advantage of young children's superior language learning abilities by beginning instruction in elementary school or earlier. When it comes to language, there's no substitute for an early start.

down the road” is syntactic. In small children, these mistake-detection responses develop slowly, starting as children transition from two-word phrases to their first full sentences, around thirty months of age. Brain responses gradually become
faster and more precisely localized through childhood and into the early teens.

There seem to be at least two sensitive periods for language learning. We already discussed the sensitive period for phonemes, in the first year or two of life, when babies' brains become specialized for representing the sounds of their native language(s). There is also a sensitive period for learning about grammar. Children's ability to acquire syntax rules declines gradually after age eight, and adults are worse than children at learning languages (see Practical tip: Teach foreign languages early in life).

Some adults manage to learn a second language to a high level of proficiency. Most of us, though, no matter how hard we study in adulthood, will always have a foreign accent and make minor grammatical errors. In contrast, there does not appear to be a sensitive period for semantic learning, as new vocabulary words can be acquired equally well at any age. The event-related potential signal for semantic violations looks the same for both native and second languages, even in people who learned their second language late in life.

Children can learn more than one native language if they are exposed to both languages early enough, but their brains appear to represent the languages at least somewhat separately. Bilingual children reach language milestones at the same age and have the same risk of language impairment as monolingual children, though the details of their language development are somewhat different. So if your household is bilingual, the research indicates that this is not a disadvantage for your child's language learning. (Indeed, it may be an advantage for cognitive development; see Practical tip: Learning two languages improves cognitive control, p. 118.) Learning a second language also changes the brain. A region in the left inferior parietal cortex is larger in people who speak more than one language, and it is largest in those who learned the second language when they were young or speak it fluently.

Infants quickly learn to identify different languages by their rhythms, their characteristic phonemes, and other cues. Bilingual children do sometimes mix languages in their speech, but they seem to do so for the same reasons and in the same situations as adult bilinguals, for instance, substituting a word from one language when they don't know the word for that concept in the other one. Though bilingual children have a smaller vocabulary in a particular language than monolingual children of the same age, bilingual children know more words in total if you count both languages.

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Children who hear more words while interacting with their parents in the first two years of life learn language faster than children who hear fewer words. These differences in home environments tend to fall along socioeconomic class lines. In one study, the poorest children heard 600 words an hour, working-class children heard 1,200 words, and children of professionals heard 2,100 words. These major differences in children’s language environment correlate with their later language development and IQ scores—though the finding that highly verbal parents raise highly verbal children may be partly due to genetic factors or the many other advantages of growing up in a professional household (see chapter 30).

Later research has shown that you can improve your children’s language skills by responding rapidly to their vocalizations, mimicking the turn-taking of conversation even before your baby is capable of forming words. Responding with a comment or a touch to your baby’s best attempts to communicate seems to encourage continued efforts to improve these skills. So talk to your baby and put up a good show of understanding what she’s saying. It’s fun for both of you, and it will help her language skills to develop more quickly.
Chapter 30

A TOUGH ROAD TO TRAVEL: GROWING UP IN POVERTY

AGES: CONCEPTION TO EIGHTEEN YEARS

Growing up under conditions of deprivation can damage children’s brains. This is an exception to the general principle we have expressed throughout this book that most children are resilient, and that variations in normal (“good enough”) parenting do not appear to have a strong influence on how they turn out as adults. This chapter is about the other side of the coin: what happens to children whose developing brains match themselves to an environment that does not encourage them to express their full potential. After all, even dandelions can’t grow in the desert.

Where your children grow up is one of the most critical factors in their development. When you move to a new house or apartment—or another country—you’re determining not only your children’s schools but also their neighborhood and the characteristics of the group from whom your children will select their friends. Children learn a lot from other kids and from the culture by which they are surrounded (see chapters 17 and 20). It’s hard to raise children to reject the attitudes and assumptions of their peers, as parents have discovered everywhere from religious communities to inner-city neighborhoods. This is one of the many reasons that children start life at a disadvantage when they grow up in places with high unemployment, unsafe streets, and poor education.

Poverty itself isn’t exactly the problem, unless children are actually starving, which is rare in developed countries. The risks instead come from conditions that are made more likely by poverty, in particular growing up in a chronic state
of fear and/or stress. Poverty is stressful due to a combination of economic insecurity (inadequate living conditions, frequent moves), disorganized households and harsh parenting (common side effects of parental stress or addiction), and social subordination (being treated as inferior because of social class and/or race). Heightened fear and anxiety can result from living in a high-crime neighborhood, food insecurity, and parental mistreatment (again more common when parents are stressed).

Inadequate parenting can and does occur in any segment of society, of course. Indeed, the middle class, because it is the biggest economic group in many countries, typically contains the largest number of chronically stressed or threatened children, as well as the largest number of children with behavioral problems. In addition, some especially resilient people who grow up in very difficult conditions become highly successful and happy adults. Even so, poor children grow up in environments that statistically increase their risk of a variety of disorders. Indeed,
some of these “problems,” such as chronic anxiety or early reproduction, may actually constitute adaptive responses to insecure living conditions (see chapter 26).

Socially and economically disadvantaged people are much more likely than middle-class people to suffer from medical, emotional, cognitive, and behavioral problems. Socioeconomic status (SES) is an umbrella term for the resources that people have available to them relative to others in their society. At minimum, it includes income, occupation (with associated prestige), and education, each of which can be broken down into more detailed measures. Across a variety of countries with different social systems, lower SES predicts substantially increased risk of a broad range of medical problems, including heart disease, respiratory disease, diabetes, and psychiatric conditions. As family SES decreases, children have increased risk of low birth weight, premature birth, infant mortality, injury, asthma, and various chronic conditions, including behavioral disorders. Community SES also influences child outcomes in studies that control for family SES.

Health and SES vary together across the full range of SES; the relationship is not merely a consequence of very poor health at the bottom of the scale. Overall, the lower people’s SES, the earlier they are likely to die, with a difference of decades in some countries between the highest- and lowest-SES groups. The gradient is steepest at the bottom, though, with the biggest step between poor and working-class groups. These differences are large. In the U.S., adults with the lowest SES are about five times more likely to report having “poor” or “fair” health than the highest-SES adults.

SES is closely connected with health even in countries with equal access to health care and for diseases that medical care cannot prevent, such as juvenile diabetes and rheumatoid arthritis. So it is not primarily due to differences in

People who are satisfied with their standard of living and feel financially secure are healthier, regardless of their actual income, occupation, and education, than people who are unsatisfied and anxious about the future.
medical care—though such differences can make the problem worse. Only part of this discrepancy (about one third, in one study of British government workers) can be explained by lifestyle differences, such as high rates of smoking and drinking, poor diet, and infrequent exercise among low-SES groups. Lung cancer is still more prevalent in low-SES than high-SES groups even when comparing people who smoke the same number of cigarettes, so there must be some problem beyond lifestyle choices.

The relationship between SES and health may be attributable to the effects of stress, which can damage the brain and the rest of the body (see chapter 26). In many species, life at the bottom of the dominance hierarchy involves chronic stress and a poorly functioning biological stress response system. You could imagine that animals with poor stress responses are just more likely to become subordinate, but researchers found that social subordination occurs first and causes poor stress responsiveness, and not the other way around.

It can be most stressful to be a high-ranking animal in some species or under special circumstances, for instance, when dominance can be maintained only by fighting a lot. But in people, it’s usually the low-ranking members of society who experience the most stress. Social status is so important to people that reducing the power or status of middle-SES adults in an experimental situation decreases their ability to concentrate, ignore distractors, and inhibit inappropriate behavior. We speculate that chronically low social status may have a similar effect on low-SES children. In one study, by age ten, children in Montreal already showed a sharp relationship between SES and cortisol, with blood levels twice as high in the lowest-SES children as in the highest-SES children.

How we interpret the circumstances of our lives also has a strong effect on our stress responses (see chapter 26)—often stronger than the effects of our actual economic circumstances. Low-SES people not only experience more chronic stresses and negative life events, but also experience ambiguous events as being more stressful, compared to higher-SES people. When people are asked to give their own position in society on a drawing of a ten-rung ladder, their ranking is a stronger predictor of health than their actual SES. People who are satisfied with their standard of living and feel financially secure are healthier, regardless of their actual income, occupation, and education, than people who are unsatisfied and anxious about the future. Along the same lines, countries, states, or cities with greater income inequality have steeper gradients of SES versus health. This may
be because income inequality interferes with the feeling of community, which provides many types of social support to counteract stress. Increased crime also correlates with income inequality—again, better than with absolute poverty. So the existence of strong inequality in society may be a major driver of stress.

Which parts of children’s brains are damaged by deprivation? We know from animal studies that chronic stress can cause structural changes in the hippocampus and amygdala (see chapter 26). In people, low subjective SES and other sources of chronic stress are linked to reduced hippocampal volume. Long-term memory, which depends on hippocampal function, is impaired in low-SES populations. In experimental animals, chronic stress can cause neurons to die, prevent new neurons from being born or surviving, and cause dendrites to become less complex (a change that is reversible) in the hippocampus. Scores on a variety of language tests also vary strongly with SES, perhaps due to the less complex language environment provided by low-SES parents (see chapter 6).

In people, the perception of low SES is associated with stronger activity in the amygdala in response to threats. That’s understandable; if you believe that you are low on the totem pole, it’s natural to feel vulnerable and therefore respond strongly to danger. Indeed such increased vigilance may reflect a sensible reaction to real dangers in the environment. The amygdala is important for rapid processing of events that induce fear and other emotions (see chapter 18), and it is extensively interconnected with the stress response system.

Across the life span, from infants to adults, low SES predicts decreased executive function, perhaps because the environment offers fewer opportunities to strengthen these abilities through practice. The medial prefrontal cortex (including the anterior cingulate and orbitofrontal regions) is an important inhibitor of the stress system. In experimental animals and people, chronic stress reduces the size of the prefrontal cortex. This brain region is involved in working memory and planning and organizing behavior (aspects of executive function), and it is also necessary for learned suppression of fearful reactions to situations that are no longer dangerous. People who perceive themselves as having low SES have reduced volume in one part of the anterior cingulate cortex. One promising intervention for low-income preschool children, Tools of the Mind, focuses on promoting behaviors that depend on the prefrontal cortex (see Practical tip: Imaginary friends, real skills, p. 117).

The causes and possible solutions to the SES-health gradient are hotly de-
bated, within the scientific community as well as in society. The key problem for research is that people aren't randomly assigned to be poor, so we can't draw conclusions about causality by comparing the characteristics of low-SES and high-SES people (see *Did you know? Epidemiology is hard to interpret*, p. 262).

Do people develop problems because they're disadvantaged? Or do they become (or remain) disadvantaged due to poor health or other problems? There is evidence in favor of both positions. The health of adopted children is best predicted by their adopted parents' income, not their biological parents' income, suggesting that family income can influence health independently of genetics. Along the same lines, childhood SES predicts adult health, as we discuss below. On the other hand, the adult income and (particularly) education of adopted children does depend partly on their biological parents' characteristics.

It's important to remember that these two classes of explanations aren't mutually exclusive. Indeed, the most likely relationship between poverty and achievement is a vicious cycle, in which starting life with few resources leads children to develop a variety of problems, which then make their life situation worse, reducing their resources (and their children's resources) still further.

Some of the relationship between SES and cognitive achievement may be attributable to exposure to environmental hazards, more common in poor neighborhoods, that can cause substantial, lasting impairment in brain function. Children exposed to lead before or during elementary school age have lower IQs and impulse control, as well as higher aggression and delinquency, compared with children of the same SES. All these problems persist through adulthood. Mercury exposure also reduces IQ, along with attention, memory, and language development.

Children who live in noisy environments, such as near airports or highways, are delayed in learning to read compared with other children of the same SES. Chronic noise exposure also causes deficits in attention and long-term memory, perhaps because it is known to increase stress hormone levels. Crowded or chaotic environments (at home or at school) impair cognitive development and academic

The existence of strong inequality in society may be a major driver of stress.

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The tools of epidemiology, appropriately, are best suited to the study of epidemics, which are caused by a single factor (a germ). The same tools are increasingly used to study conditions like heart disease, which have far more complex causes. Epidemiological studies of this kind are far more difficult to interpret and should be approached with a skeptical eye.

In a typical epidemiology study, scientists collect data on a large group of people for years and then attempt to correlate risk factors, such as excessive drinking, with health outcomes, such as deaths due to injury. Studies of this sort have serious limitations, which are rarely taken into account in your local newspaper or when health agencies make lifestyle recommendations based on their findings.

It is almost impossible to draw reliable conclusions about cause and effect from correlation data. One pitfall is reverse correlation. For instance, obesity is correlated with poverty. Does poverty lead to poor diet and lack of exercise, which then cause obesity, as is commonly assumed? Or might obesity cause poverty due to wage discrimination against fat people? Another pitfall is that an additional (unstudied) factor might cause both parts of the correlation. Harsh parenting is correlated with later antisocial behavior. Does that mean harsh parenting causes antisocial behavior? Or could it be that some parents pass along a genetic tendency to antisocial behavior to their children, who then are likely to misbehave, evoking harsh parenting, even from adoptive parents? We did not invent these two examples. In both cases, there is good evidence for the second interpretation, at least as a partial explanation of the observed correlations (see p.151 for more information on the effects of harsh parenting).

Making interpretation even more difficult, risk factors tend to travel in packs. Postmenopausal women taking hormone replacement therapy have fewer heart attacks than other women, but they are also less likely to die from homicide or accidents—effects that are unlikely to be caused by hormones. The explanation is that women who take hormone replacement therapy typically have a variety of healthy characteristics: compared to other women, they pay more attention to their health, exercise more, and
are richer, more educated, and thinner. When the risk factors are correlated with each other, it becomes very difficult to sort out causes from accidental “bystander qualities,” even if the observed correlations are strong.

Epidemiology can be very useful. The link between cigarette smoking and lung cancer was established through this technique because the correlation is large (heavy smokers have twenty or thirty times more risk than non-smokers) and the rate of lung cancer in nonsmokers is low. Many side effects of approved drugs have also been identified by epidemiology. But most lifestyle effects are small to moderate, and most of the common diseases in developed countries are influenced by multiple factors. Under those conditions, epidemiology can only generate hypotheses that must be tested by other means. Such studies should be interpreted with care and caution.

performance and increase psychological distress in both parents and children, again independent of SES. These environmental conditions are all common in the lives of low-SES children and often occur together.

Growing up in a low-SES family predicts poor health even for children whose SES improves in adulthood. For example, in a group of nuns who had been living together since early adulthood, disease risk and longevity still varied depending on their education (whether or not they had gone to college). For more than fifty years, the nuns had shared meals, housing conditions, and a very similar lifestyle, but the traces of their early experiences were still substantial, with educated sisters living an average of 3.28 years longer than less educated sisters. In general, people whose SES improves later in life gain less advantage from the change than people whose SES improves in childhood.

Children whose families move out of poverty improve in some areas but not others. One study followed 1,420 poor children in North Carolina from 1993 (at ages nine to thirteen) through 2000. American Indian families were more than twice as likely as non-Indian families to be below the poverty line when the study began. In 1996, a casino opened and began to distribute some of its profits to every person on the reservation. Children whose families moved above the poverty line showed a 40 percent decrease in antisocial behaviors during the study, while children whose families remained poor showed no change in antisocial behaviors.
In contrast, moving out of poverty had no effect on symptoms of depression and anxiety, though children who had never been poor had fewer symptoms than always-poor or ex-poor children.

If indeed poverty leads to a vicious cycle like the one we’ve described, it should be easiest to break that cycle in young children, before they fall too far behind their peers. Intensive preschool enrichment programs can have positive effects that last into adulthood, substantially increasing the odds of a poor child graduating from high school, finishing college, getting a skilled job, and owning a home. These programs can also reduce the likelihood that a child will need special education or repeat a year of school.

Mostly these effects do not depend on increasing children’s IQs. Instead the positive outcomes seem to stem from improvements in social competence, including perseverance and motivation (see chapter 13) and emotional well-being. The programs that produce these results tend to be extensive, long-lasting interventions, which require a considerable commitment from both families and funding agencies. These programs are often still cost-effective for society in the long run if they reduce the likelihood that children will need special education or repeat a year of school or that they will receive welfare payments as adults.

Intervention is difficult for exactly the same reason that it is important: because it requires interrupting the developing brain’s strong tendency to match itself to the local environment. As we’ve discussed throughout this book, evolution has made that matching process resilient and hard to disrupt. If a child’s environment is toxic, though, it can do more harm than good. Fortunately, the reward for intervening is also large—turning that child into an adult who can function successfully in a safe and productive world, like the one we all want for our children.
CHAPTER 1 The Five Hidden Talents of Your Baby’s Brain

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found an effect of breast-feeding on cognitive function, but they use an unusually
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