Biological Gateways

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Like any other living organism, a human child develops incrementally, with certain developmental milestones contingent on others. Infants cannot walk until their leg muscles have natured enough to hold them, and they cannot speak until their neurological, physiological, and gross motor development are sufficiently advanced.

The master gatekeeper in human development is the brain. The kinds of sounds an infant can make during his first year of life − cooing, then babbling, and finally recognizable words − are closely tied to maturation of the central nervous system.

The key neurological issue for language is **brain lateralization**. Human brains are "divided" into left and right hemispheres, with each hemisphere having specialized functions. Visual abilities are primarily centered in the right hemisphere and verbal abilities in the left. The degree of lateralization of these skills varies with age and sex, as well as with handedness (right versus left) and individual differences. Neurological studies indicate that brain lateralization (including lateralization of some language abilities) has probably begun by the time an infant is born. Over the next dozen years (but especially during the first five or six), the degree of lateralization increases, although the exact process by which (and the extent to which) it happens is still far from clear.

Since the greatest changes in lateralization seem to take place during the most intense period of language development, it seems logical that changes in

lateralization help drive language learning. Unfortunately, current understanding of the human brain is not sufficient to prove (or discount) the theory. Some researchers believe that abilities in new born infants to discriminate between sounds (abilities that depend upon lateralization) predict linguistic performance several years later, but such findings are as yet only suggestive.

Since we know that boys tend to lag somewhat behind girls developmentally, an obvious hypothesis is that brain lateralization proceeds more slowly in male children than in female. Ongoing research on children offers more contradictions than conclusions. Paradoxically, the clearest research findings indicate that adult men show a greater degree of lateralization for language-related processes than do women.

The emergence of language depends not only on neurological growth but on physical maturation (which, in turn, has neurological correlates). The very ability to speak presupposes changes in the vocal apparatus that begin taking place soon after birth. Vocal tract differences between newborns and adults involve not merely size but also relative placement of the component parts that enable us to speak.

In newborns, the tongue is short and broad and is contained entirely within the oral cavity. (Only later does the rear third of the tongue descend into the neck.) The hard palate (the front part of the roof of the mouth) is also relatively short and wide, unlike the sharply arched palate in adults.

But the most critical difference for speech lies in the back of the vocal tract − in the larynx and the pharynx. The larynx ("voice box") in newborns is located just at the bottom of the oral cavity, and the pharynx (which will allow for the later production of differential sound frequencies) is not yet fully formed.

During the first year of life, the larynx descends, and true pharynx is created. Why the anatomical shift? The early high positioning of the larynx permits human babies to breath through their noses and swallow (e.g., when sucking milk) at the

same time – a highly useful combination. However, this original configuration (which approximates the vocal tract of nonhuman primates) makes it physically impossible to articulate the range of distinct sounds found in human languages. Experimental attempts in the 1940s and 1950s to teach spoken language to chimpanzees were physiologically doomed. Recognition in the 1960s of the biological roadblock led to the revised strategy of teaching chimps and gorillas linguistic signing systems, capitalizing on their natural manual dexterity.

The vocal tract continues to change up through puberty, when a child's characteristic high pitch gives way to the voice of adolescence. During the roughly twelve-year odyssey, many sound patterns are predictable from the size and shape of the vocal tract.

Infants, for example, typically go through a cooing and then an early babbling period between ages 3 and 9 months, when the sounds *k* and *g* are very common (hence, the adult words *coo* and *goo* in imitation of the children's vocalizations). However, when babbling yields to articulate speech somewhere between 9 and 18 months, these *k* and *g* sounds are sometimes initially absent. What happens? The answer is anatomical. Infants, especially when lying flat on their backs, can easily produce *k* and *g* because the larynx is so high (up near the epiglottis and the soft palate). As the larynx begins to drop, producing these sounds requires more concerted effort.

Even up through age 5 or 6, children's vocal track configurations can hinder them from articulating individual sounds the way adults do. Many 2- and 3-year-olds have difficulty producing distinctions between *s* and *sh*, although they perceive the differences in the speech of others. Spectrograms of children's pronunciations of *s* and *sh* show that while the sounds are physically distinct, they are acoustically more like one another than the same sounds produced by adults. This greater similarity comes about because children's vocal tracts are smaller than adults', and

the relative size of the glottal opening (between the vocal cords) in producing these sounds also differs from the opening in mature speakers.

What happens if a young child is temporarily hindered from vocalizing normally? A small number of children need to have an endotracheal tube inserted to facilitate breathing when the upper airway is obstructed. Recent studies of infants who had breathing tubes inserted before age 13 months (and who retained the tube for more than three months) suggest that the inability to vocalize normally as an infant or toddler can hinder language acquisition. Not only is the development of proper articulation delayed, but so is mastery of other expressive language skills. Moreover, these delays sometimes do not fully surface until children are 5 or 6 years old.

While it is obvious that the natural course of neurological and physiological development sets lower bounds on the language skills of growing children, is language acquisition also related to gross motor abilities such as moving arms and legs, sitting up, or walking? Linking language with motor development may help explain some common patterns in children's early vocalization. For example, most children pass through a period (generally between 6 and 10 months) in which their babbling consists of reduplicative syllables such as *dada*, *gaga*, or *baba*. Is it mere coincidence that reduplicative babbling generally appears around the same time that other repetitive rhythmic movements are becoming common? Researchers have suggested that reduplicative babbling may be an extension of the rhythmic movements of children's hands, arms, torsos, and legs that are so characteristic of children between the ages of 5 and 12 months.

Is gross motor development linked to subsequent language acquisition? Long-standing wisdom claims a correlation between the age at which a baby sits up, stands, or walks and emerging linguistic and intellectual abilities. A number of modern researchers have added corroborating evidence and have even argued for a

relationship between early motor development and later reading skills; however, other studies have failed to reveal significant correlations between such gross motor abilities as rolling over, sitting, crawling, and walking, and toddler language skills (or general intellectual ability).

The issue of motor development raises a fundamental question about the difference between language and speech. We tend to use the terms interchangeably, although they hardly mean the same things. Speech – the normal avenue for expressing language – is not the only option. Children suffering from cerebral palsy may develop sophisticated linguistic skills without gaining normal control over their vocal apparatus. And deaf children or hearing children of deaf parents often learn some form of signing as their native language.

In its earliest stages, the development of sign as a native language (e.g., American Sign Language, British Sign Language) proceeds at a different pace from the acquisition of spoken language. On average, while hearing children do not utter their first words until around 10 or 12 months, the first recognizable sign in children raised in signing households appears somewhere between 7 and 9 months. The ten-word landmark (again, on average) is reached at around 13 months in sign and 15 months in speech. And 50 words can generally be documented for signers at 18 months and for speakers at 19 or 20 months.

Why the discrepancies? Because of differing biological development in the visual and in the auditory cortex and because gaining motor control over the hands is easier than learning to manipulate the vocal apparatus. The visual motor region of the brain seems to mature before the speech area, and the visual cortex evolves more quickly than the auditory cortex. At the same time, parental input (and feedback) is simpler with sign than with speech. Parents have an easier time in modeling, manipulating, and deciphering children's physical hand movements than in influencing and making sense of children's primitive vocal attempts.

The biological fact that we are all humans ensures a high degree of commonality in the paths towards language saturation of children everywhere. Yet our biology also plays a fundamental role in distinguishing between individual children's language development. Can we foretell a child's development by knowing her gene pool? The value of these predictions would be enormous. If we knew that late talkers tend to beget late talkers, we would worry far less when an otherwise healthy 28-month-old hasn't yet uttered his first grammatical combination.

Anecdotes abound about genetic propensities to be early or late talkers. But is there concrete evidence? Looking for a genetic basis for any developmental trait involves considerable detective work. In the case of long-studied diseases, sensory abnormalities, or obvious physical characteristics (like hair color, general body structure, or dentition), the role of heredity is often easily established. More subtle characteristics such as the propensity to become overweight or to be shy are only now being tied to genetic explanations.

Attempts to find biological bases for cognitive skills (including language) are far more tenuous. Here, the complex balance between nature and nurture is mediated by seemingly countless variables − from maternal nutrition to fetal stress to the number of siblings at home. Although every child (and every home situation) is unique, several long-term studies have probed cognitive genetic legacies by studying twins (both those reared together and those reared apart) and adopted children. Since twins tend to follow their own special course of language learning, we will focus here on adoption studies.

The extensive Colorado Adoption Project probed genetic and environmental influences on children's individual development. Researchers were especially interested in comparing the cognitive abilities of adopted and nonadopted children with cognitive skills in their biological, adoptive, and nonadoptive parents. The

data suggest that children's general intelligence correlates more clearly with biological parents than with adoptive parents and that correlations for verbal language skills become particularly clear by the time children are age 7.

Further evidence that biological parentage is a good predictor of language abilities comes from research on children who have developmental language problems. One study of second graders with difficulties in grammar, meaning, or conversational language use found that immediate members of these children's families were nine times more likely to have language problems than were the families of normal children. Another study, this one of children between ages 4 and 6 who had severe phonological problems, revealed that language disorders were common in their families as well. Still other researchers have shown that monozygotic (identical) twins are more likely than dizygotic (fraternal) twins to share problems in articulation, phonological skills, or stuttering.

Although these studies tell us little directly about early language acquisition patterns in normal children and normal families, their implications are highly suggestive. We know that rates of neurological, physiological, and gross motor development can influence the rate of early language growth. We have just seen that family genetics play a significant role in the development of our physiology, personality, and cognitive abilities. The possibilities of connections are tantalizing. If we could control for environmental conditions (a daunting challenge), we might well find a biological explanation for at least part of the variation we see across children.

When does language acquisition begin? According to Dr. F. Rene Van de Carr, a California obstetrician, fetal learning can begin several months after conception, and so he founded Prenatal University to train parents-to-be how to get a head start on early pedagogy. Dr. Van de Carr suggests, for example, that mothers begin stroking their abdomens and saying, "Stroke, I'm stroking you," and

that families make prenatal audiotapes (to be played daily with headphones on the broadened belly) to introduce Mom and Dad ahead of time, so they won't be strangers in the delivery room.

Can unborn babies really understand sounds from the outside world? Contemporary research shows that sometime between 24 and 28 weeks of gestation (during the sixth month of pregnancy), fetuses respond to sounds. The question is, What do they hear? For years, reports have trickled in that unborn babies register differential responses to music heard in the womb. One audiological study notes, for example, that when mothers-to-be listened to Mozart or Vivaldi, the fetal heart rates of their babies became steadier and the level of kicking decreased. Other selected forms of music (from Beethoven to rock) generated more violent fetal kicking.

But what about fetal perception of human speech? A team of scientists in France has been studying the reception of actual human voices from the baby's vantage point. After inserting a small microphone into the uterus to pick up speech from the "outside" and recording what was received "inside," the researchers played the tape back to independent observers. Of the 3,000 sounds recorded, the observers were able to recognize only 30 percent of them. However, when the recording of a nursery rhyme (received in the womb) was analyzed by special equipment, it became obvious that the intonation pattern on the tape was perfectly received in utero. While individual sounds are probably not perceived prenatally in any reliably distinct way, intonation patterns are.

These findings may account for some fascinating data on the auditory preferences of newborn infants. One group of psychologists has been studying how much fetuses have already learned about sounds by the time they are born. The researchers used a special nonnutritive sucking technique, where newborns easily learn to suck in one of two patterns on a nipple attached to a tape recorder to choose

between two recorded voice messages. In one study, the first recording was of the baby's mother and the second of another woman's voice. The newborns' sucking preferences were to hear their own mothers' voices, suggesting familiarity from close contact over the months while in the womb.

A second experiment, again using the sucking choice technique, called upon mothers during their last 6 weeks of pregnancy to read to their fetuses, twice a day, Dr. Seuss's rhyme-filled book *The Cat in the Hat*. Once the babies were born, experimenters offered them the opportunity to choose (through the appropriate sucking pattern) to hear their mothers read either *The Cat in the Hat* or another children's poem, *The King, the Mice, and the Cheese*, which has a different metric pattern. The newborns preferred *The Cat in the Hat*. Both of these studies suggest not only that infants can distinguish intonational differences before birth but also that they can remember what they heard before entering the outside world.

When do infants begin to distinguish between the several dozen distinct sounds in a language? While researchers have demonstrated that infants in the first few weeks of life can perceptually distinguish between basic speech sounds, it is not clear that these initial inborn skills carry over beyond age 6 or 7 months (much as newborns lose their initial ability to "walk" or infants lose their early facility in pronouncing *k* or *g*). It seems that children need to begin all over again by the time they start formulating recognizable words.

Most of what we know about young children's evolving linguistic abilities comes from the sounds they actually produce. What are the roots of articulate speech? In nearly all babies, the meanings of one or two cries (e.g., of intense pain) are easy to identify. But what about the rest of the loud vocalizations that characterize infancy? Many parents claim they can discern distinctive cries when their babies are hungry or uncomfortable or want attention, though other parents believe no such differences exist in infants' vocalizations. Over a century ago,

Charles Darwin claimed that babies cry differently when they are hungry that when they are in pain, but more recent studies have failed to garner conclusive evidence that infant cries are perceptually distinguishable or even that they are phonetically distinct.

Why do numbers of parents maintain they can detect different meanings in their infants' cries? Context is one explanation. The fact that a baby has just fallen, has been left alone too long, or is past her regular feeding time leads the listener to read meaning into the child's vocalization. Such inferences often transcend the acoustic information given. (In fact, we have no independent evidence that babies themselves are conscious of the source of their unhappiness, much as adults sometimes become grumpy when they are hungry but don't recognize why they are in ill humor.) Another possibility is that the experiments to date are flawed in design. Most studies have kept the length and intensity of crying constant and studied only qualitative differences in cries. Some researchers have suggested that the real differences lie in length of crying and in growing intensity over time, variables that have received very little attention. And there is always the possibility that some children really do vary their cries while others do not.

The first discernible noises that genuinely sound language-like typically appear around age 2 to 4 months. From deep in the back of the throat emanates a sequence sounding like *ku* or *gu*. As we have already seen, cooing is a physiological, not a linguistic, development, since the ability to coo disappears with normal maturation of the vocal tract. Somewhere between 4 and 8 months, most children begin playing with sounds in patterns we call babbling. Babbling means what it intuitively seems to: making language-like sounds that have no identifiable meaning.

What kinds of sounds do children babble? Babies have been known to utter sounds not only unknown in the language of the community around them but even

unknown in any language on record. It used to be said that children babble all the sounds possible in human language, but that claim is clearly wrong. Moreover, some children are prolific babblers, and others are not.

Common early babbling sounds include single vowels, consonants that stop the flow of air in the mouth (e. g., *p, b, t, d*), nasals (*m, n*), and consonant-vowel combinations. By age 6 months to a year, most children babble extended sequences of sounds, often repeating the same syllable (e. g., *papapa*).

If babbled sounds have no meaning, why do infants and toddlers babble? Largely for the same reasons they crawl and turn over and throw things out of their crib: to exercise their bodies and explore the world. Listen to, and watch, a 6-month-old babbling. His mouth has the plasticity of an accordion: opening and closing, narrowing and widening. Sound wells up inside from the throat, and then the articulators go to work. The lips happen to clamp shut, and you hear a *p*. The tongue gets stuck in the middle, and a *t* comes out. The velum (at the back end of the soft palate) flips down, and you get an *n*. To say that the child "intends" to babble one sound or another is to forget that sound-making at this stage is overwhelmingly a form of play.

A second function of babbling is to make social contact. If you don't know the words, you can at least go through the motions. Some 8- or 9-month-old babblers are already accomplished conversationalist. They know when it's their time to "speak" and when to be quiet. In the later stages of babbling, many children incorporate a number of intonation features from the surrounding language community, making their vocalizations sound deceptively speech-like.

As adults, we vary a good deal in when we tend to talk. Some of us prattle on when driving with a companion, while others relish the silence. Babies also differ in when they like to babble. Outgoing babies typically are at peak form when in "conversation" with adults. Other infants are more circumscribed in their

choice of babbling venues.

Is there any linguistic future in babbling? The answer depends in part on a child's babbling style. Not all children babble the same amount, the same number of sounds, or for the same number of months. Some children cease babbling around the time they utter their first words (typically around 12 months), while others continue babbling for at least another year, by which time they may have spoken vocabularies of several dozen words. Still other children progress in stages.

For children who cease babbling before the community reinforces particular sounds the children are producing, we hardly expect to find much continuity between babbling and speech. However, for children whose babbling elides into speech or continues alongside words for some months, there is growing evidence that the sounds of late babbling become the sounds of early speech.

By the time they begin using recognizable words, children have been barraged with language by parents and other caretakers (including television) for thousands of hours. In the average household, a few dozen labels for objects and actions (including such words as *mommy, daddy, milk, no*, and *up*) have especially high frequencies in the language adults emphasize to very young children. Typically children show signs of understanding dozens of words (e.g., by pointing to a picture in a book or selecting an item from a high chair tray) months or, in some cases, years before speaking the words themselves. However, given the extraordinary problem of assessing infants' language comprehension, we can only say with certainty that most children understand some words between ages 6 months and a year.

The task of identifying children's first words is often fraught with problems. For all our desire to read meaning into babble, we may overlook meaningful utterances we do not understand. We also need to keep in mind that when children begin using words to refer to objects and events in the real world, their meaning for

a word is probably not the same as ours. By the time we become adults, we have built up complex definitional networks, based on a wealth of experiences of using words in varied contexts and years of schooling during which we are taught to define words in isolation. Children's introductions to the world of meaning typically involve isolated words used in highly specific situations. A child's use of the word *daddy* may refer to all men, not exclusively his father. *Mommy* might mean "give me comfort" and not refer to people at all. In hearing children's early words, adults have no clear way of figuring out what their child's initial words really mean. During the second year of life, children's word meanings may be equally idiosyncratic, but it gradually becomes easier to puzzle out what children intend when they talk.

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