Neurological and Physiological Bases for Innate First-Language Acquisition in Infants and Applicability to Reading Literacy Transfer Pedagogy

Instinctive and Innate Processes in Human Beings

The ability in modern human beings (*Homo sapiens sapiens*) to communicate vocally became a distinctive characteristic probably in Neanderthals, approximately 200,000 to 70,000 years ago. It is generally assumed that it did not occur earlier in *Australopithecus* or *Homo erectus*. The inhabitants of the valley of Neander in what is now Germany, were probably contemporary with the genus *Homo sapiens*, and may have interacted. Fossil evidence shows that, unlike non-human primates, the development of human control of breathing—longer exhalations and shorter inhalations and greater control of abdominal muscles to expand the thorax and draw air into the lungs, and to control the release of air as the lungs deflate—crucial to the development of language ability—also required the enlargement of the vertebral canal and spinal cord dimensions, along with a larger brain.

Relevant Milestones in Learning by the Modern Human Infant

A human infant learns early that crying (an instinctive vocalization) will bring comfort, food, drink, and/or companionship. Infants also learn quickly to identify the voice of their prime caretaker. From birth to three months of age, a baby reacts to loud sounds, recognizes a familiar voice and calms down if crying, or smiles when spoken to; when feeding, the infant sucks in response to vocal sounds; coos and makes pleasure sounds; has a special way of crying for different needs; smiles when it sees a recognizable face.

From four to six-months of age, an infant follows sounds with eyes; responds to changes in voice tone; notices toys that make sounds; pays attention to music; babbles speech-like and uses many different sounds, including speech sounds that begin with /p/, /b/, and /m/; babbles when excited or unhappy; makes gurgling sounds when alone or playing with someone known. By six months of age, most babies recognize the basic sounds of their native language.

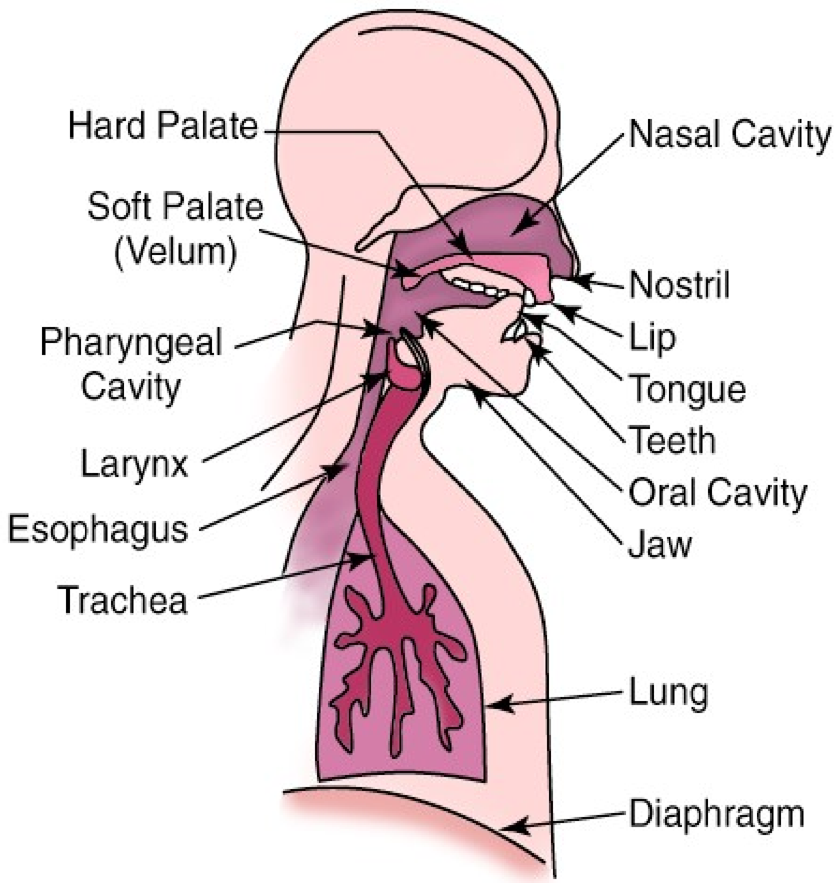
From seven months to one-year old, a child surrounded by English speakers turns and looks in the direction of vocalized sounds; listens when spoken to; understands words for common items, such as “cup,” “shoe,” “juice”; responds to requests like: “come here”; babbles, using connected speech sounds like “tata,” “upup,” “bibibi”; babbles to get and keep attention; communicates using gestures such as waving or holding up arms; imitates different speech sounds; by the infant’s first birthday the child can manage saying words like “Hi,” “dog,” “Dada,” “Mama.”

From one to two years of age, the child knows a few parts of the body and can point to them when asked; can understand simple spoken commands and questions using and connected language and syntax, such as “Roll the ball,” and “Where’s your shoe?”; enjoys hearing simple stories using connected language and syntax, songs, rhymes; can point to pictures in books when named; acquires new words and word strings on a regular basis; asks one- and two-word questions, such as “Where’s kitty?” or “Go bye-bye?”; combines words into word strings and uses more complex syntax, such as, “More cookie” or even “Want more cookie.”

From two to three years of age, a child uses two- and three-word phrases to talk about and ask for things, in a way that is understood by family members and friends; uses the sounds /k/, /g/, /f/, /t/, /d/, and /n/; names objects to ask for them or to direct attention to them.

Between three and four years, the child answers simple “Who?” “What”? and “Why?” questions; talks easily about activities at daycare, preschool, or friends’ homes: uses sentences with four or more words, as word string with connected language, and comprehensible syntax.

What the child has accomplished by age four, without formal instruction is, in part, instinctive and, in part, innate. Ingesting and drinking are both complex and instinctive. Language learning is also complex but innate.



Innate Learning

While breathing, drinking, and eating are instinctive human activities that help keep the infant and child alive, the same parts of the body, including all the senses, as well as the cognitive areas of the brain and nervous system are used by the child, innately, to learn to understand speech and also to reproduce it. A transition from the initial instinctive activity of suckling and swallowing a mother’s milk to the lip-smacking action and sound produced by the infant has led naturally to the many versions of the "Mama" sound for mother in many languages. That sound may well be the first transitional human language utterance—to innate speech production by infants.

What a human infant, toddler, and child accomplish by ages 3 or 4—almost incredibly—without instruction, but rather by means of sensory, neural, cortical, and subcortical systems is to 1) see, hear, distinguish, from among the vast variety of linked human speech sounds that they hear and see produced by adults; 2) realize that those linked speech sounds convey appropriate and specific meanings; 3) store those sounds, related meanings, lip-shapes and facial expressions in short term and long term memory; and 4) try to mimic, through perceived approval and/or encouragement signals, and eventually learn (through trial, error, and feedback) to reproduce appropriate versions of those individual utterances and linked strings of phonations randomly and/or at appropriate times.

A logical explanation for such a complex achievement by a human child exists if one considers, as Philip Lieberman has done, that such a complex human accomplishment must be due to the existence of some overarching series of interactions as in a "Functional Language System (FLS)," consisting of the premotor and motor cortex, the frontal regions of the brain, Brodmann's areas 45, 46, 47, and 8, activity in the left frontal region, in the subcortical left putamen, the posterior secondary 'auditory' cortex, Broca's area, and the posterior temporal cortex (Lieberman, 2000). It should be noted that more recent research (in 2016) referred to below considers many more cortical areas to be involved in language-related activities than previously suspected.

The Innate Procedures

A toddler determines the essential qualities of human speech production innately by hearing the entire range of complex sounds made by others, along with the facial cues that in combination suggest collectively the place of articulation, the particular kind of phonation, the probable mode of formation and reproduction of the range of those speech sounds, *simultaneously*, as well as, with time, the eventual meaning of such utterances and syntactical sequences.

The following constitute the essential parts of the human speech production anatomy:

1. diaphragm
2. lungs
3. trachea
4. larynx
5. pharynx / pharyngeal cavity
6. glottis (which is part of the larynx cavity)
7. soft palate (also called the velum)
8. uvula (which is part of the velum)
9. hard palate
10. alveolar ridge
11. roof of the mouth (which includes the soft palate + hard palate + alveolar ridge)
12. tongue
13. teeth
14. lips
15. nasal cavity

16. jaw
17. oral cavity (which includes the lips + tongue + teeth + roof of mouth + floor of mouth)

Requirements for Sound and Speech Production by an Infant
(What Infants and Children Accomplish without Instruction)

1. A power source and a vibrating element are needed to produce speech. The power source is the air that comes into the lungs; the vibration occurs in the vocal chords.
2. Instinctively, breathing in is accomplished by a lowering of the diaphragm which causes an increase of space in the thoracic cavity. The negative pressure in the lungs, compared with the atmospheric pressure, makes air rush into the nasal and oral cavities, down the trachea and into the lungs.
3. Breathing out decreases the volume of space in the thoracic cavity and positive pressure in the lungs. If the airway is open, air will rush out of the lungs, up the trachea and out through the oral and nasal cavities to equalize the pressure.
4. Phonation (the production of speech sounds) occurs in the larynx (or voice box), where the vocal cords exist. The larynx is composed of 6 cartilages, the epiglottis (a flap of cartilage at the root of the tongue, which is depressed during swallowing to cover the opening of the windpipe), the thyroid (a large ductless gland in the neck that secretes hormones regulating growth and development through the rate of metabolism), the cricoids (the ring-shaped cartilage of the larynx), the arytenoid cartilages at the back of the larynx, and the muscles and ligaments that support and connect those cartilages and form the vocal cords. Phonation occurs when air from the lungs is forced through closed vocal cords and the cords vibrate. The pitch of sounds produced in the larynx is dependent on the tension of the vocal cords. Elongation and tension in the vocal cords results in faster vibration and higher frequencies or pitch. Shortening and relaxing the vocal cords results in slower vibration and lower frequencies. The loudness of the sounds produced in the larynx is dependent on the speed of air flowing through the glottis (space between the cords). The speed is greatest when the pressure build-up below the vocal cords is high. **A child makes all these complex adjustments innately, through trial and error, without formal instruction.**
5. The vocal cords (or vocal folds) are housed inside the larynx, attached to the thyroid and arytenoid cartilages (a pair of small three-sided pyramids which form part of the larynx). They close when we swallow to protect the airway; they open when we breathe to allow air in and out of our lungs. The vocal cords vibrate open and closed during phonation.
6. Articulation of speech sounds requires learning how to use the tongue, lips, gums and/or teeth, alveolar ridges (upper and lower gums behind the teeth), the soft palate, the hard palate, the velum, the variable action of the tongue on all the structures. **An infant does all this innately, by observation, cognition, imitation, trial and error—all without instruction.**
7. **Vowels in English**: English has five vowels but they account for dozens of different sounds, depending on the linguistic environment (the word in which they are used or the connecting words). The articulation of those different vowel sounds depend upon the point and degree of constriction in the vocal tract, the degree of lip rounding or

stretching, the degree of muscle tension, the size of the mouth opening, in words such as, "miss," "mice," etc.

8. **Consonants in English**. Consonant sounds in English make up about 62% of speech in English. Their sounds vary depending on the place and the manner of articulation, and the degree of voicing. For example, there are bilabials (placing both lips together, as in /p/, /b/, /m/, /w/); labiodentals (placing lower lip and upper teeth in contact as in /f/ an /v/); dentals(placing the tongue tip in contact with upper teeth, as in /th/); alveolars (placing tip of tongue in contact or near contact with alveolar ridge, as in /t/, /d/, /s/, /z/, /n/, /l/; palatals (making tongue approach the palate, as in /j/, /r/, /-sh/); velars (placing back of tongue in contact with velum, as in /k/, /g/, /-ng/); glottals, as in /h/.
9. The manner of articulation also affects the speech sounds produced. These techniques are also learned innately by a child. For example, "stops" differ by complete or partial closure of the lips and release, as with /p/ and /b/; fricatives are created by an incomplete closure of the lips to create a turbulent sound, as in /f/, /s/, /sh/; nasals resonate through the nasal cavity, as with /m/ and /n/; speech sounds called "glides" and "liquids" are produced when the tongue approaches a point of articulation within the mouth but does not come close enough to obstruct or constrict the flow of air enough to create turbulence, as with /l/, /r/, /w/; voiced consonants are produced with the vocal cords vibrating, for example, the sounds /f/ and /v/ are both labiodental fricatives, but /f/ is voiceless and /v/ is voiced, as in "few" and "view."

Significance for Text Comprehension, Reading Instruction and Reading Competence

Good readers intuit that, although text is composed of individual letters, syllables, and words, normal and fluent reading of continuous text is not accomplished by visually constructing words by first identifying a word's alphabetic and phonetic components, sounding them out, and gradually constructing a word's appearance and meaning. That process can have disastrous pedagogical consequences. The crucial realization (by good readers) that text should be scanned visually as (and at the same rate as) normally connected speech sequences often occurs subliminally; it is not, regrettably, derived from deliberate formal instruction in U.S. schools, or normally allowed to occur. Most formal school instruction in reading begins with mistaken premises about a seemingly logical order of events that must occur, like learning how to drive a car, or learning how to play the piano, and continues to predominate with a mistaken focus, lingering too long at phonemic and syllabic levels, from which it is difficult to emerge as a proficient reader. Unless students learn early that text is merely the graphic representation of what they already know, and build on that knowledge, the vital connection between text and meaning and the need to scan groups of words that correspond to normal connected speech will escape the struggling learner. Beginning with the wrong premise can make learning to read unnecessarily unpleasant and difficult—an experience from which many never recover.

Unique Qualities of PRO that Make it Effective

PRO's unique synchronized highlighting of especially paced and phrased audio-recorded text engages the learner auditorily, visually, and semantically, while linking the crucial properties of language that naturally foster the normal subvocalization of common language sequences, supporting existing neural mapping, and synaptic connections that facilitate learning. Simply put, PRO teaches by taking advantage of a child's early language learning.

Experiments in the mid 1960's by Alan Baddeley and others on recalling a word list led them to theorize that human beings have at least two memory storage systems, in addition to working memory: one short-term phonologically based (STM), and another long-term semantically based (LTM). In the 1970's research found that human beings use language naturally as part of their thought system in general. It is nearly impossible for a literate human being to think without language. In other words the thought process naturally occurs by means of and aided by language. To a significant extent our thought processes are shaped with and limited by our language knowledge. "Phonological coding of verbal material is, in general, rapid, attentionally undemanding, and very effective for storing serial order. Semantic coding can be rapid for meaningful sequences such as sentences, but it is much harder to use for storing the order of unrelated words." (Baddeley and Levy, 1971). That makes the rational meaning of word sequences an important condition for learning language or reading, if mental binding is to occur. In other words isolated syllables or word lists are not a logical or reasonable way to increase vocabulary and/or improve literacy.

Craik and Lockhart (1972) showed that the nature of language processing requires deeper, more elaborate binding (combining results of sensory operations) if it is to lead to more effective learning. (Baddeley, 2009) used the word "chunking," to refer to a grouping "effect that makes sentences so much more readily recalled than scrambled words." Marie Carbo used the term as early as 1978 to refer to the appropriate word grouping and phrase selection in connection to semantic and phonological word groupings (at a grade-appropriate level) to refer to her audio recording technique that would naturally facilitate alphabetic and syntactical as well as visual and auditory recall. Such phrasing does facilitate recall while fostering subvocalization and retention by a learner. It is now assumed that models of serial order in verbal STM can be generalized to visual STM (Hurlstone, 2010). Further experiments in language processing suggest "a single common system" (Baddeley, 2012).

It has been found that memory subsystems (short-term, long-term, and working memory) are usable simultaneously (Logie, et al, 2000). In the case of language processing, "a single phrase can show the influence of phonological coding, at short delays, and semantic coding at longer (Baddeley & Ecob, 1970). Memory span for unrelated words is around 5, increasing to 15 when the words make up a sentence. This enhanced span for sentence-based sequences seems to reflect an important interaction between phonological and semantic systems (Baddeley et al, 1987).

The work of Baddeley (2010) also contains examples of the visual and verbal binding that likely occurs with less interference, while reading coherent sentences. Focusing on the synchronized visually highlighted audio recording of coherent text grouping found in PRO enhances binding by the learner and diminishes the possibility of distractions.

Language is innate in human beings; it is not an instinct as some have argued. Lieberman (2000) writes that "it is a learned skill based on a functional language system (FLS) that is distributed over many parts of the human brain." He adds that "the neural bases of human language are intertwined with other aspects of cognition, motor control, and emotion."

"…behavioral and neurobiological data indicate that human language is regulated by a distributed network [a functional language system, or FLS] that includes subcortical structures, the traditional cortical ‘language’ areas (Broca’s and Wernicke’s), and regions of the neocortex often associated with ‘nonlinguistic’ aspects of cognition….The FLS is a dynamic system, enlisting additional neural resources in response to task difficulty” (Lieberman, 2000, p.2).

The FLS …includes basal ganglia neuroanatomical structures that play a part in regulating sequencing when people…attempt to comprehend distinctions in meaning conveyed by syntax” (Lieberman, 2000, p.5)

The circuits of the FLS that specify specific sounds, words, and syntax of a particular language are created as children learn that language (Lieberman, 2000, p.5). The FLS accesses the sound sequences of speech by means of a rehearsal mechanism that regulates the production of speech. (Lieberman, 2000, p. 6).

“Young children can acquire the rules of grammar of any human language without any formal instruction…” because “the rules of grammar must be part of human innate knowledge” (Lieberman, 2000, p. 13).

“The basal ganglia, which are buried deep within the cerebrum, clearly play a part in human language and thought. These primitive structures, which derive from the brains of amphibians and reptiles…appear to have been modified in the course of evolution for these to work in concert with various regions of the neocortex and cortex” (Lieberman, 2000, p. 20).

The brain creates redundant computations of perceived conditions and updates memory. “Statistical regularities that can be represented as ‘rules’ will emerge as the network is exposed to a set of exemplars. Learning involves structural change, the modification of synaptic weights that build up a representation of rule-governed processes in the network’s hidden layers. As recent data demonstrate, human children likewise make use of robust, statistically driven, associative learning to ‘acquire’ the syllabic structure of words…and syntax.” (Lieberman, 2000, p. 26).

“Subcortical structures play a crucial part in regulating human language. Although Broca’s area, which consists of Brodmann’s areas 44 and 45 in the dominant, usually left hemisphere of the cortex, is usually implicated in language, children whose entire left hemisphere has been surgically removed don’t completely lose the ability to acquire language.” (Lieberman, 2000, p. 27).

There is every reason to believe that during the combined experience of the audio-visual representation of text there is neuronal coordination with the visual cortex to map the symbolic representation of speech.

“The motor command sequences that underlie the production of human speech are arguably the most complex that ordinary people attain…. The results of many independent studies …show that our brains must contain the instruction sets for ‘families’ of motor control programs for the muscles of the tongue, lips, jaw, larynx and velum that generate the same distal acoustic product—the particular formant frequency patterns, phonation or noise sources, and timing sequences that define particular speech sounds.” (Lieberman, 2000, pp.44-45). That process is in place by age three, and the mechanisms to produce those sounds can compensate to produce them even with food in one's mouth." (Lieberman, 2000, pp. 47-48).

"The incoming speech signal is hypothetically interpreted by neurally modeling the sequence of articulatory gestures that produces the best match against the incoming signal. The internal "articulatory" representation is the linguistic construct. In other words, we perceive speech by subvocally modeling speech, without producing any overt articulatory movements." (Lieberman, 2000. P. 48).

The Error of Modular Thinking

A fixation with applying modular models to the brain by Broca (1861) and Wernicke (1874), was derived from discredited phrenological theories about cranial regions associated with behavior. Regrettably such flawed views have perpetuated the distorted thinking of some regarding the best way to teach language and literacy. Modular thinking in part has led to models of learning that claim that language is produced and comprehended by means of a series of independent operations in the brain, whereby phonetic units are perceived from the acoustic signal which somehow relates to and conveys word fragments with a cumulative and rational effect. As applied to reading instruction, that kind of flawed thinking has led to a wrong-headed focus on a seemingly "logical" sequencing of arbitrary linguistic tasks that have been assumed to lead to fluent reading. Such thinking has a 100-year-old history of failure. It is now known that neurons throughout the brain create redundant systems of perceived conditions related to speech and syntax in order to update continually brain mapping and memory. Language-related tasks are built upon such systems. An infant does not learn language naturally syllable-by-syllable, but by listening to and watching adults speak normally in linked sound sequences. Children would be better served if helped to recognize the textual equivalent of the language sounds and patterns they have already learned successfully, i.e., naturally and in context. Policymakers in education have not yet caught up to the new scientific knowledge available to them that could turn failure into success for many.

A functional language system is Lieberman's name for an evolved and distributed functional neural system that acts as a network of neural circuits working together, in response to external stimuli, to the benefit of a living creature—in our case a human being. Position emission tomography (PET) studies based on brain scans conducted at the Montreal Neurological Institute have shown increased activity in Brodmann's areas 45, 46, 47, and 8 in the frontal region, as well as activity in the subcortical left putamen and in the posterior secondary auditory cortex and the posterior temporal cortex, during speech production (Lieberman, 2000). But the distribution of language-related activity in the brain and nervous system continues to broaden.

***After a remarkable five-year study to parcellate the cerebral cortex, a group of neuroscientists has recently reported on having discovered almost a hundred new cerebral areas, including a newly found area 55b, which became activated whenever the subjects heard the narration of a story (Glasser et al, 2016). That significant discovery suggests that, while using PRO, a student's area 55b would be continually activated and contributing to learning, while with any learning method that is primarily or exclusively focused and/or based on alphabetic, phonetic, syllabic, or linguistic, aspects of language, 55b would more than likely be inactive.**

Given the continued positive results that suggest the effectiveness of PRO, here is an instance in which human intuition, namely Marie Carbo's reasoned impulse to try her audio-recording method with struggling and failing students, leaped ahead of the available brain science to tackle a nagging problem in human language performance. We expect that more scientific discoveries are likely to support and explain Marie Carbo's ground-breaking work.

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