Children With Hearing Loss

Developing Listening and Talking

Birth to Six

Fourth Edition

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Preface

Childhood hearing loss is a serious and relatively prevalent condition. About 12,000 new babies with hearing loss are identified every year in the United States, according to the National Institute on Deafness and Other Communication Disorders. In addition, estimates are that in the same year, another 4,000 to 6,000 infants and young children between birth and 3 years of age who passed the newborn hearing screening test acquire late-onset hearing loss. The total population of new babies and toddlers identified with hearing loss, therefore, is about 16,000 to 18,000 per year.

The peril is that hearing loss caused by damage or blockage in the outer, middle, or inner ear keeps auditory/linguistic information from reaching the child's brain, where actual hearing occurs. Over the decades, numerous studies have demonstrated that, when hearing loss of any degree is not adequately diagnosed and addressed, insufficient auditory information reaches the brain. As a result, the child's speech, language, academic, emotional, and psychosocial development is at least compromised if not sabotaged.

In recent years, there has been a veritable explosion of information and technology about testing for and managing hearing loss in infants and children, thereby enhancing their opportunities for the auditory brain access that creates neural pathways for spoken language and for literacy. The vanguard of this explosion has been newborn hearing screening. As a result, in this day and age, we are dealing with a vastly different population of children with hearing loss, a population we have never had before. With this new population whose hearing loss is identified at birth, we can facilitate access of enriched auditory/linguistic information to the baby's brain. The miracle is that we can prevent the negative developmental and communicative effects of hearing loss that were so common just a few years ago. With these babies and young children, we can now work from a neurological, developmental, and preventative perspective rather than from a remedial, corrective one. What has happened in the field of hearing loss is truly revolutionary as we implement brain-based science.

How do we understand and manage this new population of babies and their families? How do we revise our early intervention systems to respond to the desired outcomes of listening and talking that today's parents have a right to expect? The fourth edition of *Children With Hearing Loss: Developing Listening and Talking, Birth to Six* is an exciting and dynamic compilation of crucially important information for the facilitation of brain-based spoken language for infants and young children with hearing loss.

This text is intended for undergraduate and graduate-level training programs for professionals who work with children who have hearing loss and their families. This fourth edition is also directly relevant for parents, listening and spoken language specialists (LSLS Cert. AVT and LSLS Cert. AVEd), speech-language pathologists, audiologists, early childhood instructors, and teachers. In addition, much of the information in Chapters 1 through 5, and Chapter 7, can be helpful to individuals of all ages who experience hearing loss, especially to newly diagnosed adults, as a practical "owner's manual."

This fourth edition covers current and up-to-date information about auditory brain development, listening scenarios, auditory technologies, spoken language development, and intervention for young children with hearing loss whose parents have chosen to have them learn to listen and talk. This new fourth edition now has a PluralPlus companion website with PowerPoint lecture slides for each chapter, plus relevant resource materials. There is new artwork throughout the book that illustrates key concepts of family-focused listening and spoken language intervention. All technology information has been updated, as has information about neurophysiology. The reference list is exhaustive, with the addition of the newest studies while maintaining seminal works about neurophysiology, technology, and listening and spoken language development.

Parents who are considering preschool placement for their children are referred to Chapter 6, and to the newly revised Appendix 5 for a guide to elements that need to be present in any group setting to address the unique needs of the child with hearing loss. Also, the companion website contains user-friendly versions of the "Framework for Maximizing Caregiver Effectiveness in Promoting Auditory/Linguistic Development in Children Who Have Hearing Loss" (Chapter 10), and of the "Targets for Auditory/Verbal Learning" (Appendix 3).

Appendices 7, 8, 9, and 10 provide important and useful information and tools for professionals who are interested in AG Bell Academy's Listening and Spoken Language Specialist Certification Program (LSLS)—LSLS Cert. AVT and LSLS Cert. AVEd. These appendices define and list the competencies required for the LSLS credential, and reference each chapter of the book with regard to those requirements.

This book is unique in its scholarly yet thoroughly readable style. Numerous new illustrations, tables, charts, and graphs illuminate key ideas. The fourth edition should be the foundation of the personal and professional libraries of students, clinicians, and parents who are interested in listening and spoken language outcomes for children with hearing loss.

This book is divided into two parts. Part I, *Audiological and Technological Foundations of Auditory Brain Development,* consists of the first five chapters that lay the foundation for brain-based listening and talking. These five chapters include neurological development and discussions of ear anatomy and physiology, pathologies that cause hearing loss, audiologic testing of infants and children, and the latest in amplification technologies. Part II is titled *Developmental, Family-Focused Instruction for Listening and Spoken Language Enrichment*. These second five chapters focus on intervention—listening, talking, and communicating through the utilization of a developmental and preventative model that focuses on enriching the child's auditory brain centers.

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Neurological Foundations of Listening and Talking: We Hear With the Brain

Key Points Presented in the Chapter

- About 95% of children with hearing loss are born to hearing and speaking families. Therefore, listening and talking likely will be desired outcomes for the vast majority of families we serve.
- We hear with the brain—the ears are just a way in; ears are the "doorway" to the brain for auditory information. Therefore, the problem with hearing loss is that it keeps sound/auditory information from reaching the brain.
- Because they have had 20 weeks of auditory neural experience in utero, at birth, typical infants prefer their mother's speech and songs and stories heard before birth.
- For auditory pathways to mature, acoustic stimulation of the brain must occur early (in infancy) and often, because full maturation of central auditory pathways is a precondition for the normal development of speech and language skills in children, whether or not they have a hearing loss.
- Neuroplasticity is greatest during the first 3.5 years of life; the younger the infant, the greater the neuroplasticity.
- The highest auditory neural centers (called the secondary auditory association areas in the cortex) are not fully developed until a child is about 15 years of age. The less "intrinsic" redundancy, the more redundant the "extrinsic" signal must be.
- Skills mastered as close as possible to the time that a child is biologically intended to do so, result in *developmental synchrony*.

- There is a distinction between hearing and listening.
- Hearing loss can be described as an *invisible acoustic filter* that distorts, smears, or eliminates incoming sounds from reaching the brain, especially sounds from a distance—even a short distance.

Introduction

Our biology is that we hear with the brain (Kral, Kronenberger, Pisoni, & O'Donoghue, 2016; Kral & Lenarz, 2015; Kraus & White-Schwoch, 2018). Because of brain research, newborn hearing screening, and very early use of modern hearing technologies that direct auditory information through the "doorway" to the brain to alleviate sensory deprivation and to develop multilevel neural connections, there is a new population of children with hearing loss. This new population has the benefit of brain science, language development research, and family systems research that can lead to spoken language and literacy outcomes consistent with hearing peers, if we do what it takes. What it takes is systemwide attention to all links in the Logic Chain.

As detailed in the white paper "Start with the Brain and Connect the Dots" on the Hearing First website, the Logic Chain is a model that summarizes what we know, at this point in time, about the foundational ingredients necessary to create a listening, speaking, and reading brain (Flexer, 2017).

In Part One of this book, the first five chapters, we are highlighting audiological and technological foundations of auditory brain development. Part Two, the second five chapters, will feature family-focused instruction for listening and spoken language (LSL) enrichment, designed for guiding and coaching families who have chosen a listening and spoken language outcome for their children with hearing loss. LSL also is referred to as auditory-verbal practice and auditory-verbal intervention in the literature. Auditory-verbal practice encompasses both auditory-verbal therapy (AVT) and auditory-verbal education (AVEd) and is inclusive of a child's trajectory from birth through the educational system. Auditory-verbal practice is "the application and management of hearing technology, in conjunction with specific strategies, techniques, and conditions, which promote optimal acquisition of spoken language primarily through individuals listening to the sounds of their own voices, the voices of others, and all sounds of life" (Estabrooks, 2012, p. 2).

The Logic Chain represents a system of foundational structures that must ALL be in place to optimize the attainment of a listening, spoken language and literacy outcome, if that is the family's desired outcome. No link can be skipped (Flexer, 2017).

Components of the Logic Chain: *Brain Development > General Infant/Child Language Development in the Family's Home Language > Early and Consistent Use of Hearing Technologies > Family-Focused LSL Early Intervention > LSL Early Intervention for Literacy Development*

One important goal of LSL intervention is for the children learning LSL to be on a trajectory toward achieving age-appropriate spoken language and literacy skills by third grade along with their hearing friends.

This chapter begins with the essential question for families to answer to determine the course of the child's intervention: **what is the family's desired outcome for the child?** All intervention protocols and strategies are designed to optimize the attainment of the families' desired outcome, beginning with the counseling narrative of the doorway. Next will be a discussion of two lines of research that have direct relevance regarding the crucially important connection between listening abilities and speech and language development. Following that discussion, auditory neural development is explored along with a brief explanation of neuroplasticity. An additional topic is the acoustic filter model of hearing loss. In view of all of the information in this chapter, a new context for describing deafness is posited.

Begin Conversations with the Critical Question: What Is the Family's Desired Outcome?

The bottom-line essential question for families to answer is: What is your desired outcome for your child? The family's desired outcome guides the ethical and legal provision of intervention strategies and technological recommendations.

Guiding questions for families include:

- What is your long-term goal for your child?
- How do you want to communicate with your child? What language(s) do you know and what language(s) do you want your child to know?
- Where do you want your child to be at ages 3, 5, 14, 20?

Approximately 95% of children with hearing loss are born into hearing and speaking families (Mitchell & Karchmer, 2004); these families are interested in having their child talk. In addition, many families use a main language at home other than the school language, so they likely are interested in their child speaking several languages. The coaching and intervention strategies offered by professionals are driven by the family's desired outcome.

It is suggested that practitioners refer repeatedly to the family's stated desired outcome when explaining the reason for recommendations. For example, one can explain to the family that to increase the probability of attaining the family's desired outcome of listening and spoken language for their child, the child's technology (e.g., hearing aids, cochlear implants) must be worn at least 10 hours per day.

Typical Infants: Listening and Language Development

To begin with, what is language? As reviewed in the Logic Chain white paper on the Hearing First website (Flexer, 2017), language is an organized system of communication used to share information. Spoken language consists of sounds, words, and grammar used to express inner thoughts and emotions. Language includes facial expressions, gestures, and body movements. Language is the platform for the acquisition and sharing of knowledge.

The language environment at home is the basis of an infant's brain growth and best predicts the child's language, reading, and IQ outcomes (Suskind, 2015). Language learning and knowledge acquisition begins in infancy. Because language and information are learned best in a social interaction with the people who love the baby, the parents generally become their child's first teacher and teach the child the language and knowledge of the home (Hirsh-Pasek et al., 2015; Rhoades & Duncan, 2017).

Thus, all families are advised to speak the language they know best right from the beginning, whether that language is English, Spanish, Russian, sign language, etc. Science tells us that parents should speak the language where they have the most knowledge, experience, words, and information to pass to their child to grow their child's brain with knowledge (Chen, Kennedy, & Zhou, 2012; Rhoades & Duncan, 2017). Therefore, based on the science of general early language acquisition, families of children who are deaf or hard of hearing can best provide early brain and literacy development experiences by immersing their children in the family's home language.

Research on speech perception capabilities of typical neonates, using a non-nutritive sucking paradigm, confirms that infants acquire native languages by listening; they start life being prepared to speak (Werker, 2012, 2018; Winegert & Brant, 2005). At birth, infants prefer their mother's speech, and they even prefer songs and stories heard *before* birth. How can this be? The fact is that infants are born with 20 weeks of listening experience because their cochleas are formed and functional by the 20th week of gestation (Gordon & Harrison, 2005). There is a great deal of auditory information available to the fetus in utero (Moon, Lagercrantz, & Kuhl, 2013). That is why early identification and amplification and enriched auditory-linguistic environments are essential. Newborns with hearing loss may have already missed 20 weeks of auditory brain development.

> *May et al. (2017) found that at the time human infants emerge from the womb, the neural preparation for language is specialized to speech, due to spoken language being heard in utero. At birth, the human brain responds uniquely to speech.*

In the first months of life, babies can discriminate many speech sounds, even those not heard in their home-spoken language(s). However, within a few months, the brain becomes a more efficient analyzer of speech. By the end of the first year, there is a functional reorganization of the brain to distinguish phonemes specific to language(s) heard daily (Choi, Black, & Werker, 2018). This neural reorganization improves and tunes the phonetic categories required for the infant's language and attenuates those phonemic distinctions not required for the infant's mother tongue (Vouloumanos & Werker, 2007; Werker, 2012, 2018).

At 6 months of age, babies can remember words they hear in short passages, if those words follow their own names and *not* someone else's. They can also recognize words that come after "Mommy," showing that babies are processing the speech stream from the top down, using words they know (Golinkoff, 2013). Babies are born pattern seekers, eager to learn and highly social because they learn best with people present (Caskey, Stephens, Tucker, & Vohr, 2011). Within the first year, infants have some sense of causality, gravity, paths of motion, and spatial aspects of objects (Pulverman, Song, Golinkoff, & Hirsh-Pasek, 2013). By 17 months of age, phonetic distinctions guide new word learning as infants use their phonetic categories as the foundation for learning new words (Werker, 2012, 2018).

> *When the word "listening" is used, what is meant is purposeful attention by the child to auditory information as evidenced by activation of the prefrontal cortex (Musiek, 2009).*

Thus, listening experience in infancy is critical for the development of both speech and language in young children, and a strong auditory language base is essential for reading and learning (Robertson, 2014; Sloutsky & Napolitano, 2003; Zupan & Sussman, 2009). Figure 1–1 displays this progression. Given that listening is the core event, how much listening experience is necessary for adequate language development?

Hart and Risley (1999) explored the issue of language experience in their extensive, longitudinal study of person-spoken words heard by children ages birth to 4 years. Electronic words (e.g., from TV, books on tape, computer, etc.) were not counted. Some of their results are described below.

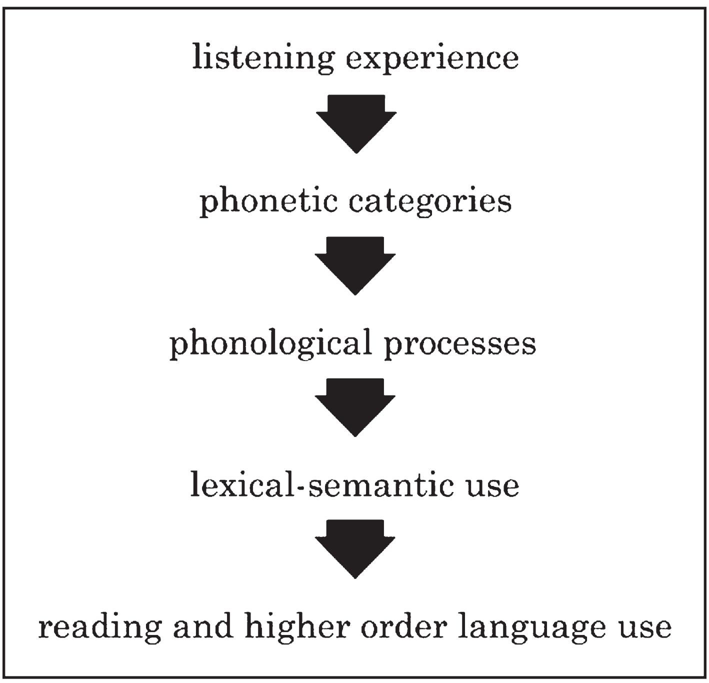

Figure 1–1. Listening experience in infancy is critical for adequate language development, and adequate language development is essential for reading.

The average number of words per hour addressed to children by parents (Hart & Risley, 1999, p. 169) is as follows:

- 2,100 in a professional family
- 1,200 in a working-class family
- 600 in a family receiving welfare

Hart and Risley (1999) noted that, “The extra talk of parents in the professional families and that of the most talkative parents in the working-class families contained more of the varied vocabulary, complex ideas, subtle guidance, and positive feedback thought to be important to cognitive development” (p. 170).

They further explained that, “Parents who talked a lot about such things [ideas, feelings, or impressions] or only a little ended up with 3-year-olds who also talked a lot, or talked only a little” (Hart & Risley, 1999, p. xii).

Hart and Risley concluded that their data “show that the first 3 years of experience put in place a trajectory of vocabulary growth and the foundations of analytic and symbolic competencies that will make a lasting difference to how children perform in later years” (Hart & Risley, 1999, p. 193).

The bottom line is that all infants and children require a great deal of listening experience—about 20,000 hours in the first 5 years of life—to create the neural infrastructure for literacy (Dehaene, 2009; Suskind, 2015). These data collected on typical infants and children have significant implications for children with hearing loss.

> *Human beings are organically designed to listen and talk if we do what it takes to access the brain with auditory information (through technology for children with hearing loss, within the first weeks of life) and practice, practice, practice listening and interacting using spoken language and reading.*

Auditory Neural Development

The problem with hearing loss is that it keeps sound from reaching the brain (Figure 1–2). The purpose of a cochlear implant (or a hearing aid) is to access, stimulate, and grow auditory neural connections throughout the brain as the foundation for spoken language, reading, and academics (Gordon, Papsin, & Harrison, 2004; Kral et al., 2016; Sharma & Nash, 2009). Due to the limited time period of optimal neural plasticity, age at implantation is critical—younger is better (Dettman et al., 2016; Ching et al., 2018; Fitzpatrick & Doucet, 2013; Geers et al., 2011; Northern & Downs, 2014; Sharma et al., 2005; Sharma & Nash, 2009).

> *The brain, unlike any other organ, is essentially unformed when one is born, and brain development is completely dependent on environmental experience. So that’s why, in the first 3 years of life, the foundation for all thinking and learning is being built through parent talk and conversational interaction.*

Studies in brain development show that sensory stimulation of the auditory centers of the brain is critically important and influences the actual organization of auditory brain pathways (Berlin & Weyand, 2003; Boothroyd, 1997; Chermak, Bellis, & Musiek, 2014; Clinard & Tremblay, 2008; Sharma & Glick, 2018).

Figure 1–2. We hear with the brain—the ears are just a way in. Hearing loss is not about the ears; it is about the brain. © Dreamstime.com

Furthermore, neural imaging has shown that the same brain areas—the primary and secondary auditory areas—are most active when a child listens and when a child reads. That is, phonological or phonemic awareness, which is the explicit awareness of the speech sound structure of language units, forms the basis for the development of literacy skills (Pugh, 2005; Robertson, 2014; Strickland & Shanahan, 2004; Tallal, 2004).

Clearly, anything we can do to access and "program" those critical and powerful auditory centers of the brain with acoustic detail will expand children's abilities to listen and learn spoken language. As Ching, Zhang, and Hou (2019) contend, early and ongoing auditory intervention is essential.

Important neural deficits have been identified in the higher auditory centers of the brain due to prolonged lack of auditory stimulation and, furthermore, the auditory cortex is directly involved in speech perception and language processing in humans (Chermak & Musiek, 2014a; Kretzmer, Meltzer, Haenggeli, & Ryugo, 2004; Kral et al., 2016; Sharma & Glick, 2018; Sharma & Nash, 2009; Shaywitz & Shaywitz, 2004). For auditory pathways to mature, acoustic stimulation must occur early and often because normal maturation of central auditory pathways is a precondition for the normal development of speech and language skills in children.

> *Sound processing is one of the most computationally demanding tasks the nervous system has to perform (Kraus & White-Schwoch, 2019). The task relies on the exquisite timing of the auditory system, which responds to input more than 1,000 times faster than the photoreceptors in the visual system. Humans can hear faster than they can see, taste, smell, or feel.*

Research also suggests that children who receive implants very early (in the first year of life) benefit more from the relatively greater plasticity of the auditory pathways than do children who are implanted later within the developmentally sensitive period (Ching et al., 2018; Kral et al., 2016; Sharma, Dorman, & Kral, 2005). These results suggest that rapid changes in P1 latencies and changes in response morphology are not unique to electrical stimulation but rather reflect the response of a deprived sensory system to new stimulation. Gordon and colleagues (2003, 2004) concurred and reported that activity in the auditory pathways to the level of the midbrain can be provoked by stimulation from a cochlear implant (CI). The hypothesis that early implantation appears to be promoted by changes in central auditory pathways was supported by evidence provided by Gordon and colleagues (2003, 2004) and by Kral et al. (2016).

Robbins et al. (2004) and Suskind (2015) found that skills mastered as close as possible to the time that a child is biologically intended to do so results in *developmental synchrony*. As human beings, we are preprogrammed to develop specific skills during certain periods of development. If those skills can be triggered at the intended time, we will be operating under a developmental and not a remedial paradigm. That is, we will be working harmoniously within the organic design of the human structure. When we intervene later in a child's life, out of harmony with the typical developmental process, we are forced to work within a remedial model. A brain can only organize itself around the sensory stimulation that it receives. Remedial intervention means that we need to undo the neural organization that the brain has initially acquired and reorganize the brain around different stimuli. A remedial model takes longer and typically has reduced outcomes because the child is now neurologically and psychosocially out of synchrony with the typical developmental process. Think of how long it takes an adult to learn to ski. It is a very long and effortful time, compared with the amount of time that it takes a child to learn to zoom down the hill.

> *Acting in harmony with a structure can be illustrated by a child learning to pump on a swing. When the child first begins to try to make the swing move without being pushed, the child expends a great deal of energy but the swing moves only a little bit. Then something happens, and the child learns how to move in harmony with the swing. As a result of child and swing synchrony, a little bit of energy input by the child causes large movement by the swing (Figure 1–3). In an analogous fashion, a developmental model allows for synchrony of intervention and development, promoting large and rapid gains.*

Mastery of any developmental skill depends on *cumulative practice;* each practice opportunity builds on the last one. Therefore, the more delayed the age of acquisition of a skill, the further behind children are in the amount of cumulative practice they have had to perfect that skill relative to their age peers. The same concept holds true for cumulative auditory practice. Delayed auditory development