START WITH THE BRAIN AND

Connect the Dots:

Supporting Children Who Are Deaf or Hard of Hearing to Develop Literacy Through Listening and Spoken Language

HEARING FIRST
Powering Potential

Foreword

There is evidence of progress over the last decade in the quest for research to inform the practices for teaching a child who is deaf or hard of hearing to develop literacy through Listening and Spoken Language (LSL). Yet, the dissemination of the research in a logical and organized way for parents and professionals to understand and use, has remained a challenge.

Recognizing this challenge and need, Hearing First commissioned Dr. Carol Flexer, Distinguished Professor Emeritus of Audiology, University of Akron, to gather, analyze and synthesize the latest supporting research. This paper is the result of her work. Organized as a logic chain, each piece of the chain is critical and builds one upon the other, beginning with brain biology and moving through to the development of literacy in the early school years. We are sharing the logic chain with the field so that families, professionals and policy makers may refer to it as they develop and deliver LSL intervention and related services. Together we will power the potential of all children who are deaf or hard of hearing.

Kindest Regards,

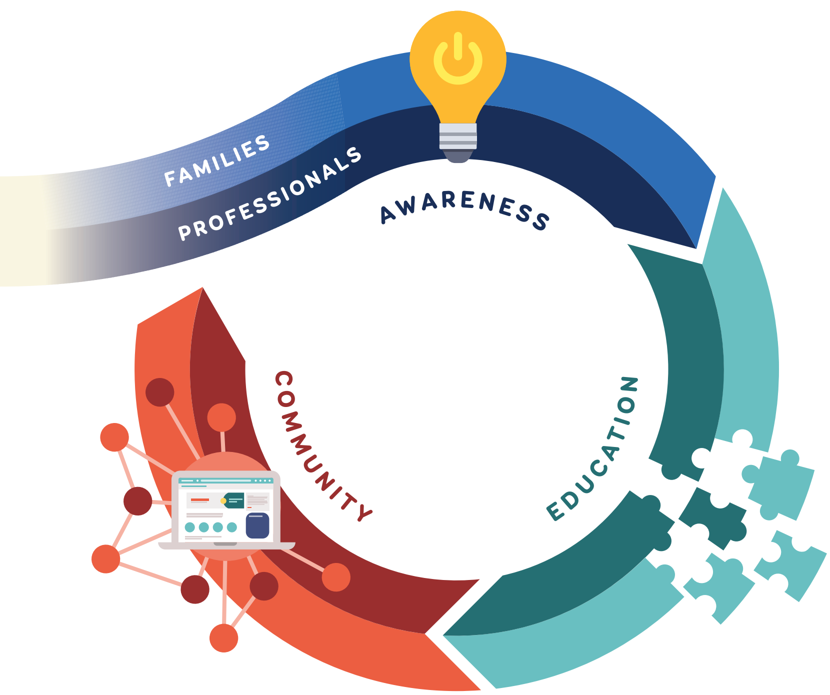
Teresa H. Caraway, PhD, CCC-SLP, LSLS Cert. AVT
CEO
Hearing First

About Hearing First

Today, children who are deaf or hard of hearing can achieve learning and literacy outcomes on par with their hearing friends. At Hearing First, we exist to support the families and professionals on the Listening and Spoken Language (LSL) journey through Awareness, Education and Community.

Awareness

Hearing First informs families and professionals of the importance of newborn hearing screening and the Listening and Spoken Language (LSL) opportunities for children who are deaf or hard of hearing.



Education

Hearing First learning experiences and resources equip families and professionals with the knowledge and skills needed to maximize LSL outcomes for children.

Community

Hearing First provides a Family Support Community and a Professional Learning Community as an online connection point for each to share, grow and learn on the LSL journey.

Hearing First is dedicated to strengthening the lives of LSL families and professionals so children who are deaf or hard of hearing can learn to listen and talk. Together, we can power potential.

Acknowledgment

Hearing First gratefully acknowledges the work of Carol Flexer in compiling the following white paper comprised of the latest evidence-based information relating to brain development, listening and spoken language and the road to literacy for children. We recognize the importance of her tireless work and collaboration in developing this resource that can be used for greater knowledge and understanding for the LSL professional field, families of children who are deaf or hard of hearing on the LSL journey, and the general public.

Carol Flexer, PhD, LSLS Cert. AVT

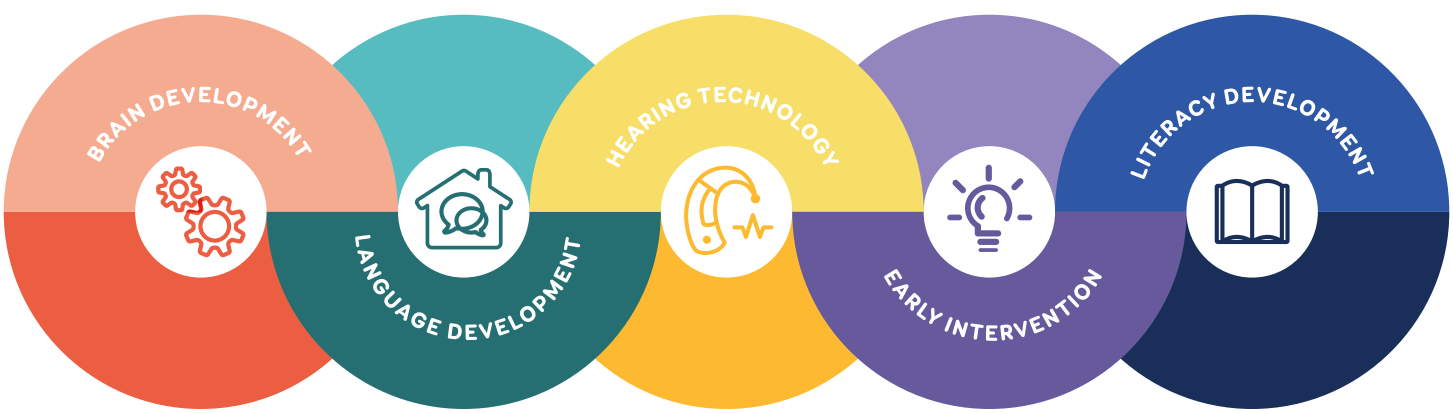
Carol Flexer, PhD, CCC-A, LSLS Cert. AVT is Distinguished Professor Emeritus of Audiology, The University of Akron. An international lecturer in pediatric and educational audiology and author of more than 155 publications including 14 books, Dr. Flexer is a past president of the Educational Audiology Association, the American Academy of Audiology, and the AG Bell Academy for Listening and Spoken Language. For her research and advocacy for children with hearing loss, Dr. Flexer has received four prestigious awards: two from The Alexander Graham Bell Association for the Deaf and Hard of Hearing -- the Volta Award and Professional of the Year Award; one from the American Academy of Audiology, the 2012 Distinguished Achievement Award; and one from Kent State University, The EHHS Hall of Fame Distinguished Alumni Award, 2015.

The purpose of this paper

is to identify the logic and research underlying what we know about how today's children with hearing loss develop literacy through listening and spoken language. As professionals, we are working with a new generation of children who are deaf or hard of hearing—a generation that is not only benefiting from advances in early hearing screening and the use of advanced hearing technology, but a generation that is also the beneficiary of what we now know about brain development, early childhood development, and language and literacy development. Below is our Logic Chain and samples of supporting research to connect the dots between basic biology and the development of literacy during elementary school. The Logic Chain summarizes what we know, at this point in time, about the ingredients necessary to create a reading brain. **Specifically, 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; no link can be skipped.**

In this paper, we are spotlighting the integrated role that family-focused Listening and Spoken Language (LSL) intervention plays for the 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 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, pp 2). One important goal of LSL intervention is for the children learning LSL to be on a trajectory toward achieving age-appropriate literacy skills by third grade along with their hearing friends. For purposes of our Logic Chain, we are setting literacy in the family's home language and in the language of the school, if it is different, as our desired result, recognizing that other outcomes at other ages and stages are also important to a child's overall development.

In addition, this paper specifically does not address research relating to sign language development and the supports children using a sign language system with their family need in order to develop the same literacy trajectory. There likely would be overlap between our Logic Chain and a Logic Chain developed to illustrate the inputs and connections needed for a sign language learner to develop grade-level reading along with his or her hearing friends. Most notably, we know that all children need a language-rich learning environment and consistent access to loving, fluent adults who can share the depth of experience and the richness of language information with them. However, a review of the research related to the connections between sign language development and the literacy trajectory are outside the scope of this work.



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Auditory Brain Development

Activation and stimulation of the baby's auditory brain centers begins 20 weeks before birth when the inner ear is fully developed. Typically developing babies, therefore, are born with 20 weeks of auditory neural exposure.

The overall foundational neural architecture of a baby's/child's brain is built primarily before their first birthday. The resultant neural architecture is dependent on the richness of the environment, especially the depth of experience and language input by important family members in the child's world. The richer the information, the more detailed will be the brain growth and proliferation of neural synapses. This concept is known as "experience dependent plasticity". The point is, timing is critical. We should think of the early stimulation of the infant's brain with auditory information as a neuro-developmental emergency that is necessary to address if we want to achieve our literacy goal.

Sample and Brief Summaries of Articles about Auditory Brain Development and the Auditory Cortex

Cardon, G., Campbell, J., & Sharma, A. (2012). Plasticity in the developing auditory cortex: Evidence from children with sensorineural hearing loss and auditory neuropathy spectrum disorder. Journal of the American Academy of Audiology, 23, (6), 396-411(16).

The authors report that the auditory cortex is highly plastic (aka "neuroplastic," i.e., the ability of neuronal groups to adjust function based on auditory input) particularly during the first 3.5 years of life with respect to visual, auditory, and pre-frontal cortices. By 12 months of age, the cortex has generally developed all six layers, and by age 4 years "pruning" occurs. During pruning, extraneous synapses and neurons that do not contribute to the (same) system are eliminated from the specific sensory system (likewise, "neurons that fire together, wire together"). Indeed, age 3.5 years has been described as the end of the "sensitive period" for cochlear implantation in congenitally deaf children. Multiple studies have shown significantly improved outcomes for children implanted earlier in infancy, rather than later.

Two major components impact clinical outcomes: (1) the quality and quantity of auditory information (to the cortex) and (2) the timing of the input/auditory information. Of note, the mere existence of (normally) developed intrinsic (organic) pathways cannot guarantee normal transmission or function of sensory information—extrinsic (environmental) stimulation is of significant importance, too. The authors report that if environmental input, such as spoken language conversation/information, is not delivered to the auditory cortex during periods of optimal plasticity, deficits will remain, even after auditory stimulation occurs.

Kral, A. (2013). Auditory critical periods: A review from system's perspective. Neuroscience, 247: 117-133.

The article reviews evidence for sensitive periods in sensory systems and considers their neuronal mechanisms from the viewpoint of the system's neuroscience. Kral reviews the essential cortical developmental steps, and shows that neural development is dependent on environmental experience.

Kral, A., Kronenberger, W. G., Pisoni, D. B., & O'Donoghue, G. M. (2016). Neurocognitive factors in sensory restoration of early deafness: A connectome model. The Lancet Neurology, 15(6), 610-621.

Kral, A., & Lenarz, T. (2015). How the brain learns to listen: Deafness and the bionic ear. E-Neuroforum, 6(1):21-28.

Kral, A., & Sharma, A. (2012). Developmental neuroplasticity after cochlear implantation. Trends in Neurosciences, 35(2): 111-122.

These articles review evidence that auditory deprivation has widespread effects on brain development, affecting the capacity to process information beyond the auditory system. After sensory loss and deafness, the brain's effective connectivity is altered within the auditory system, between sensory systems, and between the auditory system and centers serving higher order neurocognitive functions. The brain is a dynamic self-organizing system that develops based on reciprocal experiences between neural activity and stimulation from the environment. Auditory experience provides temporal patterns to the developing brain, which could be important for developing sequential processing abilities such as pattern detection, sequential memory, and sustained attention in general. As a result, limitations in auditory experience during development might affect neurocognitive functioning well beyond spoken language.

The results of Dr. Kral's studies suggest that when the brain does not have access to intelligible speech during the early years of a child's life, meaningful auditory input does not coordinate activity between the primary and secondary auditory cortex. Instead, the secondary auditory cortex assists with the processing of other functions such as visual processing. Additionally, auditory stimulation beyond the critical period of language development finds disordered functional interactions between the primary and secondary auditory cortex, further complicating auditory learning.

The disconnection between primary and secondary cortex has significant functional implications for auditory and spoken language development. When auditory signals are not efficiently and effectively transmitted from primary to secondary auditory cortex, the secondary cortex cannot distribute spoken language and other meaningful sounds/information to the rest of the brain to create auditory meaning and knowledge; this negative process is called "downstream degradation". Kral uses this connectome model of deafness to explain inter-individual variations in cochlear implant outcomes.

The bottom line is, babies/children must have very early access to intelligible speech and meaningful acoustic information to fully develop all auditory areas of the brain for optimization of spoken language, knowledge and literacy capacity. Hearing is a stepping stone to cognition.

Hearing is a stepping stone to cognition.

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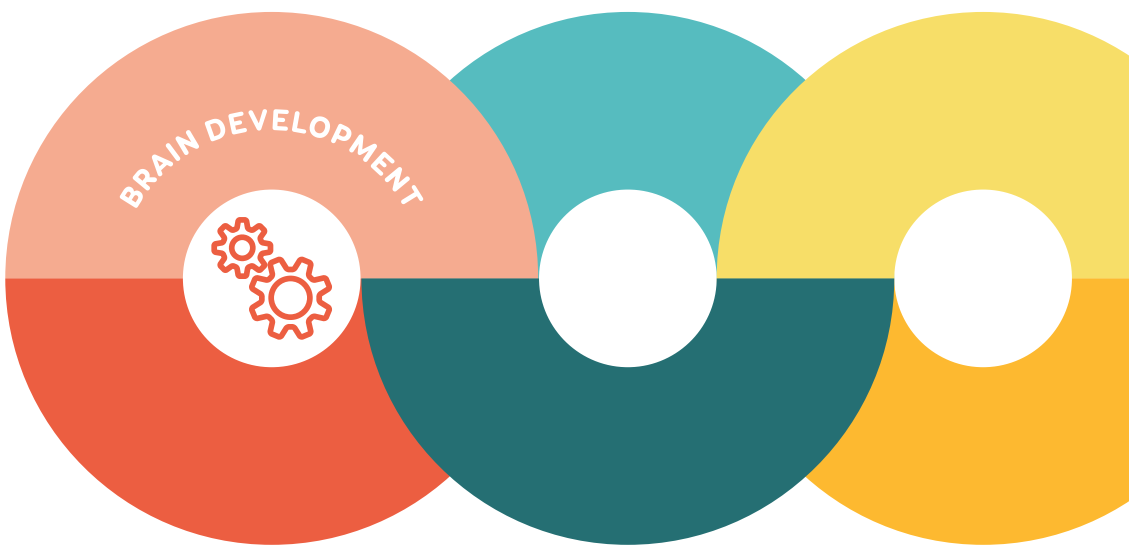
Moon, C., Lagercrantz, H., & Kuhl, P. K. (2013). Language experienced in utero affects vowel perception after birth: A two-country study. Acta Pædiatrica, 102(2),156-160.

Infant phonetic perception can be measured shortly after birth by noting differences in responding to familiar vs. unfamiliar vowels. Therefore, the ambient language (e.g., the mother's speech) to which the brains of fetuses are exposed in the womb, affects their perception of their family language at a phonetic level.

Summary of Auditory Brain Development for Children with Hearing Loss

“Hearing” can be defined as brain perception of auditory information. Children who are born deaf or hard of hearing or who acquire hearing loss at a young age do not have the same opportunities, biologically, for their auditory neural development to progress at the same rate as their hearing friends. So, children with hearing loss whose parents want a spoken language outcome, must be appropriately fitted with hearing technology (e.g., hearing aids or a cochlear implant) by an audiologist as early as possible (in the first weeks of life for newborns) to mitigate any periods of auditory neural deprivation and to provide brain access to a rich and robust model of intelligible speech and fluent language information. The early fitting of technology will nourish the auditory cortex and promote synaptic connections between the primary and secondary auditory cortex as well as establish functional neural networks between the secondary auditory cortex and the rest of the brain. Through all of these neural connections, the child’s brain will be able to make incoming sound possess higher-order meaning, which is critical to language, knowledge, and literacy development.



General Infant/Child Spoken Language Development in the Family's Home Language

To begin with, what is language? Simply put, 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. Language learning and knowledge acquisition begins in infancy. Because language/information is learned best in a social interaction with the people who love the baby, it is the parents who generally become their child's first teacher and teach the child the language and knowledge of the home.

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, in order to grow their child's brain with knowledge. 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.

95% of children with hearing loss are born to hearing families; less than 1% of the U.S. population is fluent in sign language.

22% of U.S. families do not speak English at home, so their children will need to know at least two spoken languages -- the language of the home and also the language of school.

Sample and Brief Summary of Articles about Spoken Language Development Focusing on Audition and the Family's Home Language

Caskey, M., Stephens, B., Tucker, R., & Vohr, B. (2011). Importance of parent talk on the development of preterm infant vocalizations. Pediatrics, 128(5), 910- 916.

Preterm infants begin to make vocalizations at least 8 weeks before their projected due date and significantly increase their number of vocalizations over time. Exposure to parental talk was a significantly stronger predictor of infant vocalizations at 32 weeks and conversational turns at 32 and 36 weeks, than language from other adults. These findings highlight the powerful impact that parent talk has, even for preterm infants, on the appearance and increase of vocalizations.

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Chen, S. H., Kennedy, M., & Zhou, Q. (2012). Parents' expression and discussion of emotion in the multilingual family: Does language matter? Perspectives on Psychological Science, 7(4), 365-383.

Parents regularly use words to express and discuss emotion with their children. The results in this study suggest that self-reported expressivity and observed emotional expression have more impact when delivered in the family's home language. The family's home language carries critical emotional content and social expressions.

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Hart, B., & Risley, T.R. (1999). The social world of children: Learning to talk. Baltimore: Brookes Publishing Company.

This book summarizes a landmark study of child language development. The authors found that 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 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" (Hart & Risley, 1999, 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 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 (talk, read and learn) in later years" (Hart & Risley, 1999, p. 193).

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Hirsh-Pasek, K., Adamson, L.B., Bakeman, R., Owens, M.T., Golinkoff, R.M., Pace, A., Yust, P.K.S., & Suma, K. (2015). The contribution of early communication quality to low-income children's language success. Psychological Science, 26(7), 1071-1083.

Suskind, D. (2015). Thirty million words: Building a child's brain. New York: Penguin Random House.

These publications offer research about the importance of family conversation in the development of every baby/child's language and neural/cognitive capacity. In the first three years of life, there

The family's home language carries critical emotional content and social expressions.

is more rapid and robust brain growth than during any other time; 80 to 85 percent of the physical brain develops during this time. Humans are born with 100 billion neurons, but those neurons are meaningless without connections. Those neural connections are developed by parent talk and interaction. The brain, unlike any other organ, is essentially unformed when one is born, and brain development is completely dependent on this environmental experience. So that's why, in the first three years of life, the foundation for all thinking and learning is being built through parent talk and interaction.

The Suskind book provides tips for family conversation based on the 3 "Ts". The first T is "Tune In." Tune into what the child is interested in, follow his or her lead, or get the child interested in what the parent is doing. The second is "Talk More." When talking, use rich and varied vocabulary. Lastly, is "Taking Turns." View the child as a conversational partner from day one.

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Vouloumanos, A. & Werker, J.F. (2007). Listening to language at birth: Evidence for a bias for speech in neonates. Developmental Science, 10(2), 159-164.

The nature and origin of the human capacity for acquiring language is not yet fully understood. The authors reveal the source of this capacity by demonstrating that humans are born with a preference for listening to speech. Human neonates adjusted their high amplitude sucking to preferentially listen to speech, compared with complex non-speech stimuli. These results support the premise that human infants begin language and information acquisition with a predisposition for listening to speech.

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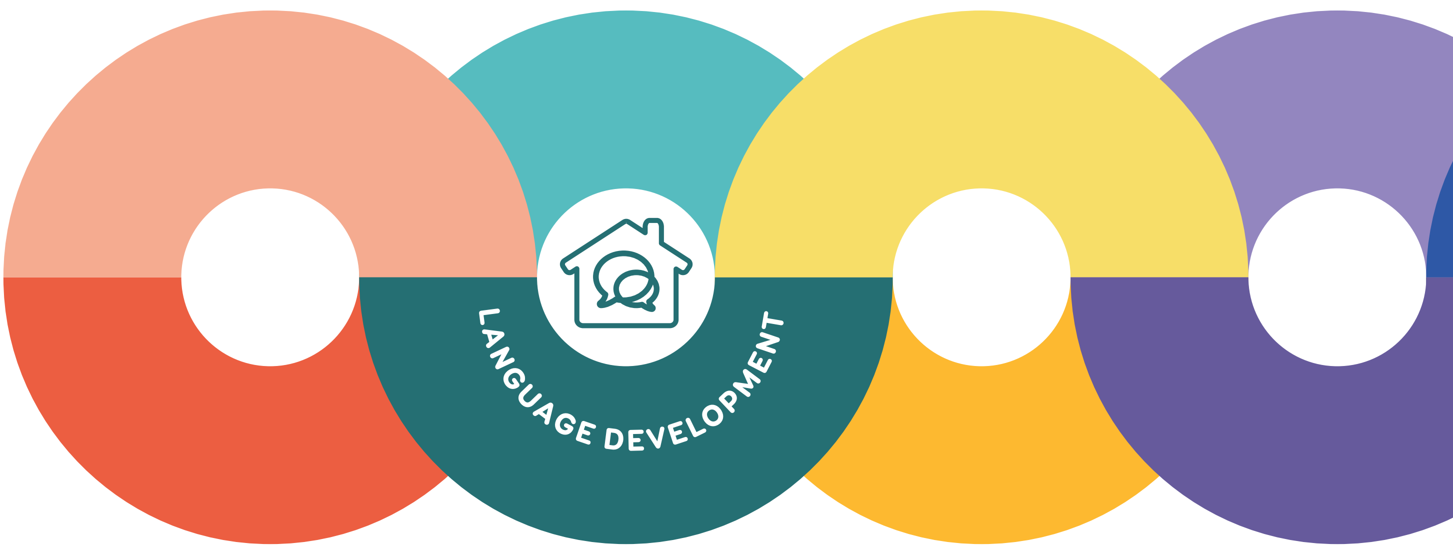
Zupan, B., & Sussman, J.E. (2009). Auditory preferences of young children with and without hearing loss for meaningful auditory-visual compound stimuli. Journal of Communication Disorders, 42, 381-396.

The authors conducted several investigations. The first experiment examined modality preferences in children and adults with normal hearing to combined auditory-visual stimuli. The second experiment compared modality preferences in children using cochlear implants who had been participating in an auditory-emphasized therapy approach, to the children with normal hearing from the first experiment. A second objective in both investigations was to evaluate the role of familiarity in these preferences. Participants were exposed to randomized blocks of photographs and sounds of ten familiar and ten unfamiliar animals in auditory-only, visual-only and auditory-visual trials. Results indicated an overall auditory preference in children, regardless of hearing status, and a visual preference in adults. Familiarity affected modality preferences only in adults who showed a strong visual preference to unfamiliar stimuli. The comparable degree of auditory responses in children with hearing loss who were in an auditory-based therapy program, to those from children with normal hearing, lends support to an auditory emphasis for intervention.

Summary of Infant/Child Spoken Language Development for Children with Hearing Loss

Science tells us that babies are born with a preference for auditory stimuli and a bias toward listening to speech. This bias is also true for babies who are deaf or hard of hearing and who receive early brain access to auditory information through hearing technology. That is, children with hearing loss likely will progress with their hearing friends as auditory learners when given early brain access through hearing technology and LSL intervention. Like their hearing friends, children with hearing loss need high quality and quantity of auditory-language information in order to develop their knowledge and cognitive capacity. The research has shown that high volume and fluent language interactions during a baby's earliest years will establish the neurological foundation for future learning and literacy development. Therefore, following a developmental model, children with hearing loss need to be fitted with hearing technology in early infancy in order to hear the voices of their parents speaking and sharing information in the language of the family.



Early and Consistent Use of Hearing Technologies

Our biology is that we hear with the brain. The ear is the structure that captures raw, vibratory sound from the environment and directs it to the brain; but it is the brain that processes and gives meaning to that auditory information.

Our ears are merely “doorways” to our auditory neural centers. Authentic “hearing” occurs in the brain, and not in the ears, just like “seeing” occurs in the brain and not in the eyes. Hearing loss, therefore, can be viewed as an obstruction in the doorway that prevents a little, a lot, or all auditory information from reaching the brain. To over-simplify -- hearing loss is a “doorway problem,” and spoken language development depends on overcoming the doorway problem and getting information to the brain. Hearing technologies (e.g. hearing aids, cochlear implants, bone anchored devices and remote microphone systems) are engineered to break through the ear/doorway to allow access, activation, stimulation, and development of auditory neural pathways with auditory information, including spoken language.

Therefore, the only point of wearing hearing technologies is to get auditory information through the doorway to the brain. With the availability of newborn hearing screening, we can identify a doorway problem at birth so we can -- and must -- fit auditory technologies in the first weeks of life to activate and grow auditory neural connections as a foundation for language and knowledge development. It should be noted that while hearing aids can be fit within days of birth, cochlear implants, currently appropriate for babies with severe to profound hearing loss, are not able to be surgically implanted until 6-12 months of age, depending on the protocols of a particular country. Therefore, hearing aids are fit in early infancy before cochlear implants, to activate auditory neural connections as the first step in the continuum of hearing technology.

Sample and Brief Summary of Articles about Early Use of Hearing Technologies

Dettman, S.J., Dowell, R.C., Choo, D., Arnott, W., Abrahams, Y., Davis, A., Dornan, D., Leigh, J., Constantinescu, G., Cowan, R., & Briggs, R.S. (2016). Long term communication outcomes for children receiving cochlear implants younger than 12 months: A multi-centre study. Otology and Neurotology, 37(2): e82-e95.

The purpose of this study was to examine the influence of age at implant on speech perception and on language and speech production outcomes in a large, unselected pediatric cohort. This study prospectively gathered available assessment data, from 1990 to 2014, from three Australian centers. Subjects were 403 children with congenital, bilateral, severe to profound hearing loss who received cochlear implants under 6 years of age. A variety of speech and language measures were employed. Data revealed a significant effect for age-at-implant for all outcome measures. Cognitive skills also accounted for significant variance in all outcome measures except open-set phoneme scores. Results support the advantage of providing cochlear implants before 12 months of age for children with severe to profound hearing loss for the optimization of speech perception, speech production accuracy and subsequent spoken language acquisition.

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Dillon, H., Cowan, R., & Ching, T.Y. (2013). Longitudinal outcomes of children with hearing impairment (LOCHI). International Journal of Audiology, 52, (Suppl 2: S2-3). doi: 10.3109/14992027.2013.866448.

Although the importance of early identification and intervention is well-established, the Longitudinal Outcomes of Children with Hearing Impairment (LOCHI) study has provided further clarification on the impact of early amplification on language outcomes of children with hearing loss. In the study, 75% of the participating families chose to use an exclusively LSL mode of communication with their children.

The LOCHI study has provided world-first evidence for the benefits at 5 years of age of early hearing-aid fitting by 6 months or cochlear implantation younger than 12 months of age, combined with educational intervention for auditory language development of children.

Background: The LOCHI study is a population-based, prospective study that directly compares the outcomes of children with hearing loss who received early or later intervention (https://www.nal.gov.au/project/longitudinal-outcomes-of-children-with-hearing-impairment-lochi-study/). The study includes approximately 450 children with hearing loss born in NSW, Queensland, and Victoria between 2002 and 2007. Depending on the stage of implementation of universal newborn hearing screening (UNHS) programs in the respective states at the time, the hearing loss of children was identified via either UNHS or standard care. Nonetheless, all the children shared the same post-diagnostic, free, expert audiological services from Australian Hearing, with a loss to follow-up rate of less than 1%. This means that the results of the children can be fairly compared, whenever and wherever their hearing loss was discovered. The uniqueness of the study on the world scene has been recognized with on-going grant funding from the U.S. National Institutes of Health, which enables the children to be followed up to age 9 years.

The LOCHI study has provided world-first evidence for the benefits at 5 years of age of early hearing-aid fitting by 6 months or cochlear implantation younger than 12 months of age, combined with educational intervention for auditory language development of children.

Fagan, M.K. (2014). Frequency of vocalization before and after cochlear implantation: Dynamic effect of auditory feedback on infant behavior. Journal of Experimental Child Psychology, 126, 328-338.

The motivation for infants' non-word vocalizations in the second half of the first year of life and later is unclear. This study of hearing infants and infants with profound hearing loss with and without cochlear implants addressed the hypothesis that vocalizations are primarily motivated by auditory feedback. Early access to cochlear implants (in this case by 18 months) has created unique conditions that permit empirical tests of relationships between auditory perception and infant behavior. Evidence from two separate tests showed that before cochlear implantation, infants with profound hearing loss vocalized significantly less often than hearing infants; however, soon after cochlear implantation, they vocalized at levels similar to hearing peers. These results support the observation that auditory feedback (hearing oneself) is a critical component that motivates the frequency of infant vocalizations.

Houston, D. M., et al. (2012). Word learning in deaf children with cochlear implants: Effects of early auditory experience. Developmental Science, 15(3), 448-461.

Word-learning skills were tested in normal-hearing 12- to 40-month-olds and in children with severe to profound hearing loss from 22- to 40-months of age and 12 to 18 months after cochlear implantation. All subjects were tested for their ability to learn two novel-word/novel-object pairings. Children with normal hearing learned this task at approximately 18 months of age and older. For children who were deaf, performance on this task was significantly correlated with early auditory experience. Children whose cochlear implants were switched on by 14 months of age or who had relatively more hearing before implantation demonstrated learning in this task, but later implanted children with profound hearing loss did not. Performance on this task also correlated with later measures of vocabulary size. The results of this study suggest that early auditory experience facilitates word learning.

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Leigh, J.R., Dettman, S.J., & Dowell, R.C. (2016). Evidence-based guidelines for recommending cochlear implantation for young children: Audiological criteria and optimizing age at implantation. International Journal of Audiology, S55, S9-S18.

The purpose of this study was to establish up-to-date evidence-based guidelines for recommending cochlear implantation for young children. Speech perception results for early-implanted children (under 3 years of age) were compared to children using traditional amplification. Language of early-implanted children was assessed over six years and compared to hearing peers. Speech perception outcomes suggested that children with a pure tone average (PTA) greater than 60dB HL have a 75% chance of benefitting from a CI over traditional amplification. More conservative criteria applied to the data suggested that children with PTA greater than 82dB HL have a 95% chance of benefit. The authors concluded that children with hearing loss, under 3 years of age, may benefit from cochlear implantation if their pure tone average (PTA) exceeds 60dB HL, bilaterally. Implantation as young as possible should minimize any spoken language delay resulting from an initial period of auditory neural deprivation caused by a lack of auditory information to the brain.

Children fit early with hearing aids had better early language achievement than children fit later.

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McCreery, R.W., Walker, E.A., Spratford, M., Bentler, R., Holte, L., Roush, P., Oleson, J., Van Buren, J., & Moeller, M.P. (2015). Longitudinal predictors of aided speech audibility in infants and children. Ear & Hearing, 36, pp. 24S-37S.

The Outcomes of Children with Hearing Loss (OCHL) study, conducted by researchers at the University of Iowa, Boys Town National Research Hospital, and the University of North Carolina at Chapel Hill, examined the impact of early identification and intervention on children with hearing loss. The study collected data from 317 children who are hard of hearing and a comparison group of 117 children with normal hearing. The children were recruited from locations surrounding the three collaborating sites and ultimately came from 17 states.

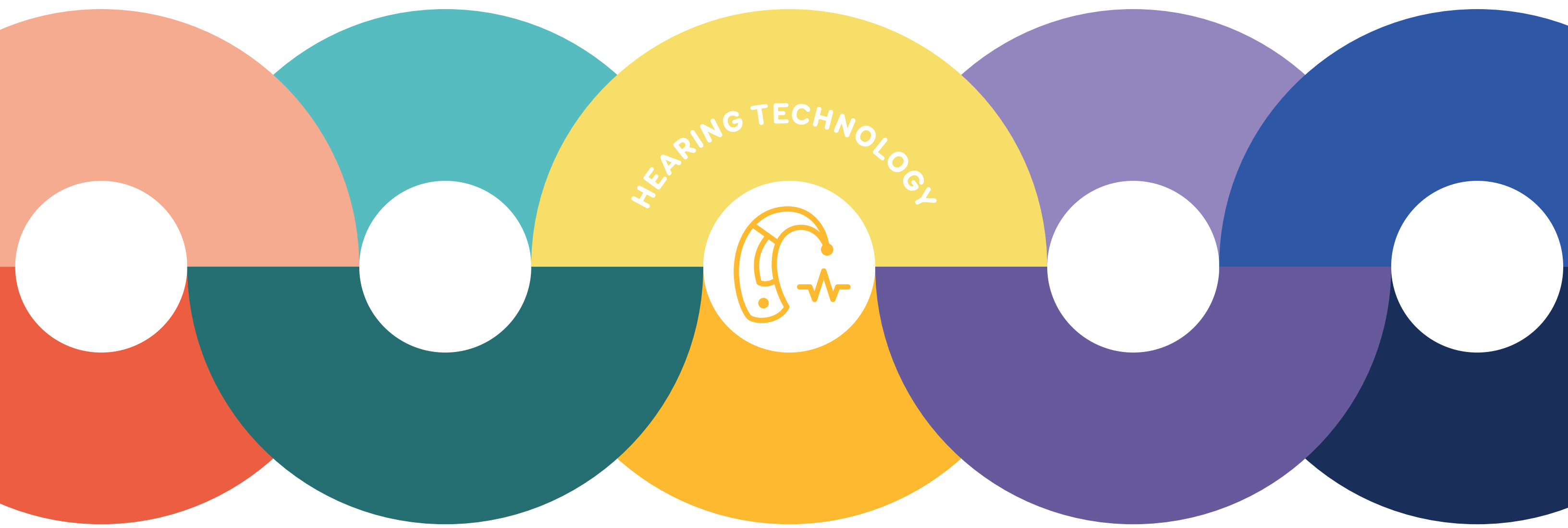
The following results were revealed: hearing aid provision in early infancy results in better early language outcomes; children who were fit later showed delays in language development although this delay diminished with extended hearing aid use; consistent daily hearing aid use (at least 10 hours per day) provides some protection against language delay and supports auditory development; the richness of parents' or caregiver's talk with the child influences child language outcomes. Better audibility with hearing aids was associated with faster rates of language growth in the preschool years. Children fit early with hearing aids had better early language achievement than children fit later, especially if they wore their hearing aids at least 10 hours per day and were in an environment with enriched caregiver conversations.

Sininger, Y.S., Grimes, A., & Christensen, E. (2010). Auditory development in early amplified children: Factors influencing auditory-based communication outcomes in children with hearing loss. Ear & Hearing, 31(2), 166-185.

For the children in this study, the age at fitting of amplification ranged from 1 to 72 months, and the degree of hearing loss ranged from mild to profound. Age at fitting of amplification showed the largest influence and was a significant factor in all outcome models. The degree of hearing loss was an important factor in the modeling of speech production and spoken language outcomes. Cochlear implant use was the other factor that contributed positively to speech perception, speech production, and language outcomes. Children with the earliest (brain) access to the speech signal/information through amplification, overall, will have the best outcomes on auditory-based communication measures.

Summary of Early and Consistent Use of Hearing Technologies

The studies on the use of hearing technologies confirm what we would expect from our knowledge of brain development and language development. Access to sound/auditory information and fluent and abundant language interactions during the critical periods of brain and early childhood development is essential. For families choosing an LSL outcome, children who are deaf or hard of hearing must be fit by an audiologist with appropriate hearing technology as early as possible, wear the devices at least 10 hours per day, be monitored audiologically to prime their brains for spoken language and knowledge development, and be immersed in a conversation-enriched environment.



Family-Focused LSL Early Intervention

If, through the use of technology, the child who is deaf or hard of hearing is offered a developmentally appropriate, enriched, family-focused and social, spoken language environment,

then that infant/child can develop a "hearing brain," and attain age-appropriate spoken language outcomes. The addition of intentional and family-focused listening and spoken language intervention is necessary so that the child does not lag behind in their reading and academic skills.

The child's brain needs continuous enrichment with intentional exposure to auditory information (e.g. more conversations and read alouds, active teaching of phonemic awareness, maybe additional tutoring) because (1) we are making up for lost time and the delay in auditory brain access, and (2) although they are very effective, auditory technologies are not perfect. A child using hearing technology will miss some casual auditory information that is floating around the environment due to distance from the signal or noise in the environment. Therefore, listening, which is purposeful attention to auditory information as evidenced by activation of the prefrontal cortex (Musiek, 2009), must be taught to the child. To summarize, LSL family-focused early intervention with an emphasis on listening, is critical for children with hearing loss to maximize the effectiveness of their hearing technology, and catch up to and maintain pace with their hearing friends in terms of language and knowledge development (Estabrooks, MacIver-Lux & Rhoades, 2016; Rhoades & Duncan, 2017).

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Eriks-Brophy, A., Ganek, H., & DuBois, G. (2016). Evaluating the research and examining outcomes of auditory-verbal therapy. In W. Estabrooks, K. MacIver-Lux, & E. A. Rhoades, eds. Auditory-Verbal therapy. (pp. 35-94). San Diego: Plural Publishing.

Lim, S. R, & Hogan, S.C. (2017). Research findings for AV practice. In E.A. Rhoades, & J. Duncan, eds. Auditory-verbal practice: Family centered early intervention, 2nd ed. (pp. 52-64). Springfield, IL: Charles C. Thomas.

There are a number of studies investigating listening and spoken language intervention – also known as auditory-verbal therapy (AVT). Two current chapters offer first-rate examinations of AVT studies. A chapter by Eriks-Brophy, Ganek and Dubois (2016) focuses on evidence informed practice (EIP). EIP uses both scientific research outcomes and insights from practitioners and families for decision-making regarding auditory-verbal therapy. A chapter by Lim and Hogan (2017) scrutinizes current research, identifies study limitations and details future research needs for auditory-verbal therapy. Both chapters are excellent and detailed sources of information.

Sample and Brief Summary of Articles about Family-focused LSL Early Intervention

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Ching, T.Y. (2016). Population outcomes of children with hearing loss: Early treatment is crucial, but not sufficient. American Academy of Audiology Conference, Phoenix, Arizona.

Dillon, H., Cowan, R., & Ching, T.Y. (2013). Longitudinal outcomes of children with hearing impairment (LOCHI). International Journal of Audiology, 52, (Suppl 2: S2-3. doi: 10.3109/14992027.2013.866448.

The LOCHI study has provided world-first evidence for the benefits at 5 years of age of early hearing-aid fitting prior to 6 months or cochlear implantation close to 6 months of age, combined with educational intervention for language development of children.

Children receiving AVT for 50 months had speech, language and self-esteem levels similar to their hearing peers and comparable reading and math scores.

75% of participating families chose to use an exclusively LSL mode of communication with their children.

Receiving spoken language only, in early intervention made a significant positive difference in language outcomes at age 3 and age 5. This finding is to be expected given the fact that the vast majority of children in the study were born to parents with normal hearing. Therefore, the family's natural mode of teaching and communicating with their child was via spoken language. This study finding is relevant for professionals who counsel families on the important considerations in selecting a communication mode for children with hearing loss.

Also, there was a positive effect of higher cognitive ability and maternal education.

Background: The Longitudinal Outcomes of Children with Hearing Impairment (LOCHI) study is a population-based, prospective study that directly compares the outcomes of children with hearing loss who received early or later intervention. The study includes approximately 450 children with hearing loss born in NSW, Queensland, and Victoria between 2002 and 2007. Depending on the stage of implementation of universal newborn hearing screening (UNHS) programs in the respective states at the time, the hearing loss of children was identified via either UNHS or standard care. Nonetheless, all the children shared the same post-diagnostic free, expert audiological services from Australian Hearing, with a loss to follow-up rate of less than 1%. This means that the results of the children can be fairly compared, whenever and wherever their hearing loss was discovered. The uniqueness of the study on the world scene has been recognized with on-going grant funding from the U.S. National Institutes of Health, which enables the children to be followed up to age 9 years.

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Dornan, D., Hickson, L., Murdoch, B., & Houston, T. (2007). Outcomes of an auditory-verbal program for children with hearing loss: A comparative study with a matched group of children with normal hearing. The Volta Review, 107(1), 37-54.

Children enrolled in AVT program and who received parent-focused intervention performed similarly to typically developing peers on speech and language assessments.

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Dornan, D., Hickson, L, Murdoch, B., & Houston, T. (2009). Longitudinal study of speech perception, speech, and language for children with hearing loss in an auditory-verbal therapy program. The Volta Review, 109(2-3), 61-85.

Children receiving AVT for over 21 months improved their live voice speech perception, language and speech scores significantly and in a similar fashion to their hearing peers. Both groups were in the normal range for receptive vocabulary development, but the typically hearing group outperformed the children in AVT. These results are similar to the LOCHI studies.

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Dornan, D., Hickson, L., Murdoch, B., Houston, T., & Constantinescu, G. (2010). Is auditory-verbal therapy effective for children with hearing loss? The Volta Review, 110(3), 361-387.

Children receiving AVT for 50 months had speech, language and self-esteem levels similar to their hearing peers and comparable reading and math scores. Over time, and with ongoing attention to spoken language and literacy development, continual improvements were made, consistent with their hearing peers.

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Eriks-Brophy, A., Durieux-Smith, A., Olds, J., Fitzpatrick, E., Duquette, C., & Whittingham, J. (2012). Communication, academic, and social skills of young adults with hearing loss. The Volta Review, 112(1), 5-35.

Young adults who received AVT in childhood and were supported throughout their school years were successful in mainstream environments. They performed comparably to their typically hearing peers on communication and self-perception assessments as well as in academic achievement.

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Eriks-Brophy, A., Gibson, S., & Tucker, S. (2013). Articulatory error patterns and phonological process use of preschool children with and without hearing loss. The Volta Review, 113(2), 87-125.

While typically hearing children outperformed children in AVT on articulation and phonologic processing assessments, the children in AVT had phonologic processing systems that resembled their peers' and most demonstrated at least 12 months' progress in 12 months' time.

Early communication mode exerts a powerful influence on early outcomes that persist into later years.

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Fulcher, A., Purcell, A., Baker, E., & Munro, N. (2012). Listen up: Children with early identified hearing loss achieve age appropriate speech/language outcomes by 3 years-of-age. International Journal of Pediatric Otorhinolaryngology, 76(12), 1785-1794.

Children who were early diagnosed, received amplification by 3 months of age, AVT by 6 months, and cochlear implants by 18 months, did not demonstrate a delay of speech and language skills by age 3.

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Geers, A.E., Strube, M.J., Tobey, E.A., Pisoni, D.B., & Moog, J.S. (2011). Epilogue: factors contributing to long-term outcomes of cochlear implantation in early childhood. Ear & Hearing, 32(1 Suppl.), 84S-92S.

This epilogue report focuses on how speech perception, speech production, language, and literacy performance in adolescence is influenced by a common set of predictor variables obtained during elementary school. Use of an LSL mode of communication positively influenced verbal rehearsal speed, which was a strong predictor of all early outcomes, which in turn strongly influenced later outcomes. These analyses suggest early communication mode exerts a powerful influence on early outcomes that persist into later years. Phonological processing skills, reflected in word attack and spelling skills, also were associated with teenagers achieving the highest literacy scores.

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Hogan, S., Stokes, J., & Weller, I. (2010). Language outcomes for children of low income families enrolled in auditory-verbal therapy. Deafness and Education International, 12(4), 204-216.

Children with hearing loss living in low income families can attain listening and spoken language outcomes if the appropriate intervention is provided. Socio-economic status (SES) did not play a role in spoken language outcomes for the children in this AVT study.

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Lew, J., Purcell, A., Doble, M., & Lim, L. (2014). Hear here: Children with hearing loss learn words by listening. International Journal of Pediatric Otorhinolaryngology, 78(10), 1716-1725.

Intervention directed at listening alone improves vocabulary and speech skills without having to focus on them as specific goals.

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Morrison, H. (2012). Co-articulation in early vocalizations by children with hearing loss: A locus perspective. Clinical Linguistics and Phonetics, 26(3), 288-309.

Children who received hearing aids by 5 months had anticipatory coarticulation patterns similar to typically developing peers. Anticipatory coarticulation patterns were affected by whether or not the child had acquired that syllable before or after cochlear implantation.

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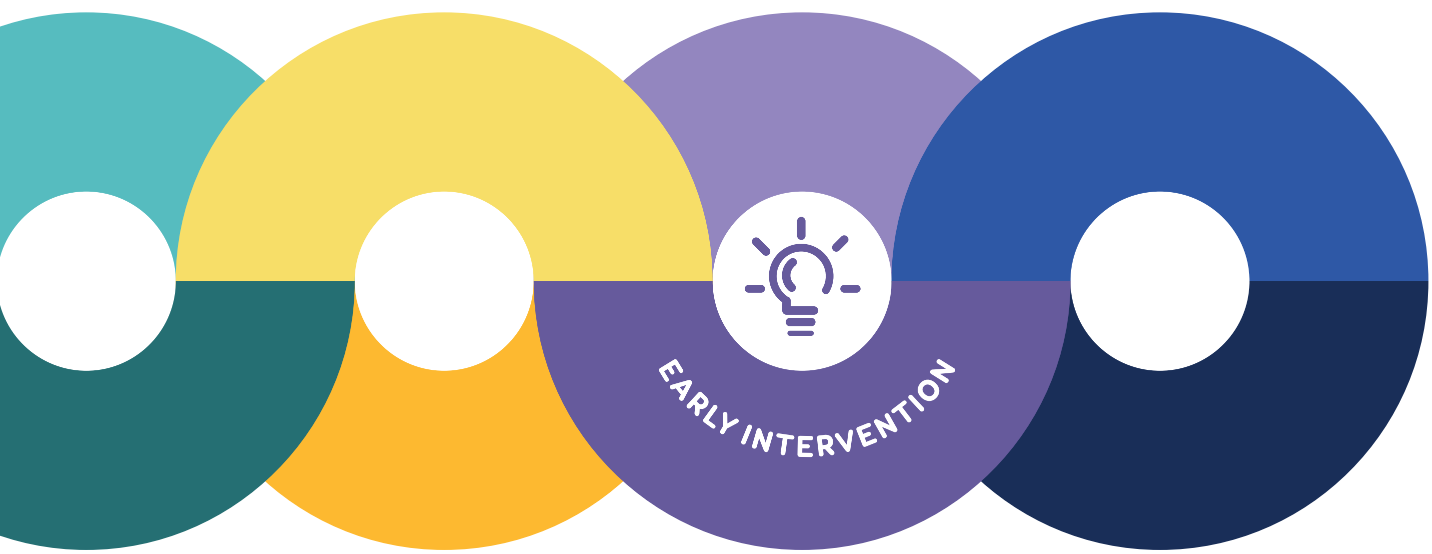
Sahli, A. & Belgin, E. (2011). Researching auditory perception performance of children using cochlear implants and being trained by auditory-verbal therapy. The Journal of International Advanced Otology, 7(3), 385-390.

A combination of cochlear implants and parent-focused AVT improved auditory perception and expressive speech and language skills in children with hearing loss.

Summary of Family-Focused LSL Early Intervention

Intentional family-focused listening and spoken language intervention, guided by a skilled LSL professional, is a necessary link in the Logic Chain. The child's brain needs continuous enrichment with deliberate exposure to auditory information, such as conversations and read alouds, from the very beginning. Studies show that receiving spoken language only in early intervention, made a significant difference in language outcomes at age 3 and age 5. In fact, children enrolled in AVT programs and who received parent-focused intervention, performed similarly to typically developing peers on speech and language assessments. These analyses suggest that early LSL intervention, integrated with the other elements of the Logic Chain, generates positive LSL outcomes that persist into later years and that forms the basis of literacy development.



Listening and Spoken Language (LSL) Early Intervention for Literacy Development

Literacy is tied to knowledge - word/sound knowledge and world knowledge. In fact, in today's world, the word literacy can have an even broader meaning than simply reading and writing.

Literacy can include being good in math, having technology skills and being able to solve problems. High levels of literacy are needed to do well in school and in a job, and will open doors for life-long career flexibility and success.

If reading in the family's home language (and in the language of the school, if that is different), is a basic literacy outcome for all children, including children who are deaf or hard of hearing, then those children need to be exposed to the family language from the first days of infancy to impact brain development and the creation of neural pathways required for listening, talking and reading. Children also should be read aloud to, daily. In fact, studies show that reading aloud is one of the most important activities we can do with our children. Why? Because (Robertson, 2014):

- Exposure to storybooks is the biggest factor in a preschooler's vocabulary.
- More parent-child conversations occur during read alouds than during any other activity.
- Children who receive read-alouds show gains of more than twice as many new words.
- Reading aloud to children before age 6 affects language, literacy and reading development. (http://trelease-on-reading.com/)

Sample and Brief Summary of Articles about LSL Early Intervention for Literacy Development

Ching, T.Y. (2016). Population outcomes of children with hearing loss: Early treatment is crucial, but not sufficient. American Academy of Audiology Conference, Phoenix, Arizona.

Dillon, H., Cowan, R., & Ching, T.Y. (2013). Longitudinal outcomes of children with hearing impairment (LOCHI). International Journal of Audiology, 52, (Suppl 2:S2-3). doi: 10.3109/14992027.2013.866448.

It is well known that children with hearing loss are at risk for delays in literacy development. The LOCHI study researchers wanted to identify the most important factors associated with literacy development in children with hearing loss. The researchers have found that phonological awareness made a significant contribution to children's reading ability (for both words and non-words), after controlling for variations in receptive vocabulary, cognitive ability, and a range of demographic variables. Dr. Ching and her team have found that children who have deficits in phonological awareness also struggle to develop age-appropriate literacy skills. The researchers learned that a significant number of children with hearing loss struggle to develop even basic phonological awareness abilities. This link between phonological awareness and literacy development is very relevant. Early interventionists must evaluate phonological awareness skills in children with hearing loss, and provide enriched, early intervention to support its development.

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Fairgray, E., Purdy, S., & Smart, J. (2010). Effects of auditory-verbal therapy for school-aged children with hearing loss: An exploratory study. The Volta Review, 110(3), 407-433.

After 20 weeks of AVT, children showed improvement in speech perception, speech production, and receptive language measures. There was less improvement shown in the area of reading. This study, like the LOCHI study and Dornan studies, shows that extra attention needs to be paid to reading development, beginning with phonological awareness.

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Geers, A. (2016). Emergence of literacy in Children with prelingual profound hearing loss. American Academy of Audiology Conference, Phoenix, Arizona.

Geers, A.E., Mitchell, C.M., Warner-Czyz, A., Wang, N.Y., Eisenberg, L.S., & the CDaCI Investigative Team. (2017). Early sign language exposure and cochlear implantation benefits. Pediatrics, 140(1). e20163489

Predictors of better reading outcomes include: earlier implantation or less duration of deafness, education of the mother and higher family SES, better speech production, better language, better phonological skills, and mainstreaming. Strong support was provided for the benefits of spoken language input from the start for promoting verbal and literacy

Better readers were in LSL programs from the beginning. Early sign language use before or after CI did not offer any advantage. In fact, early use of sign language interfered with the acquisition of phonological awareness.

development in children implanted by 3 years of age. In this study, better readers were in LSL programs from the beginning. Early sign language use before or after CI did not offer any advantage. In fact, early use of sign language interfered with the acquisition of phonological awareness.

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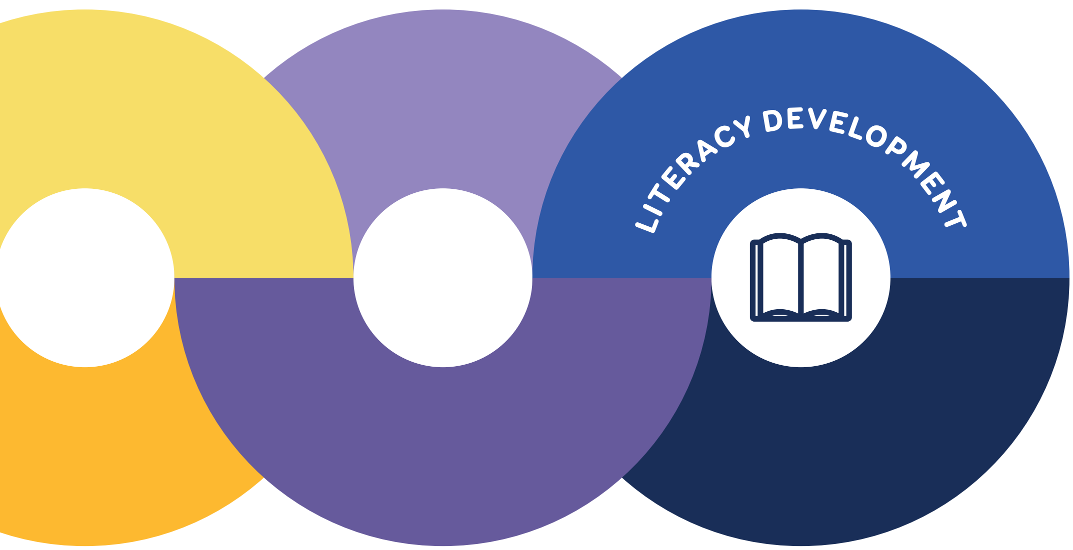
Von Muenster, K., & Baker, E. (2014). Oral communicating children using a cochlear implant: Good reading outcomes are linked to better language and phonological processing abilities. International Journal of Pediatric Otorhinolaryngology, 78(3), 433-444.

Children with hearing loss who used cochlear implants and who had higher language and phonologic processing skills, had better reading outcomes. These outcomes are similar to the LOCHI study.

Pay attention to phonological awareness as well as to knowledge acquisition!

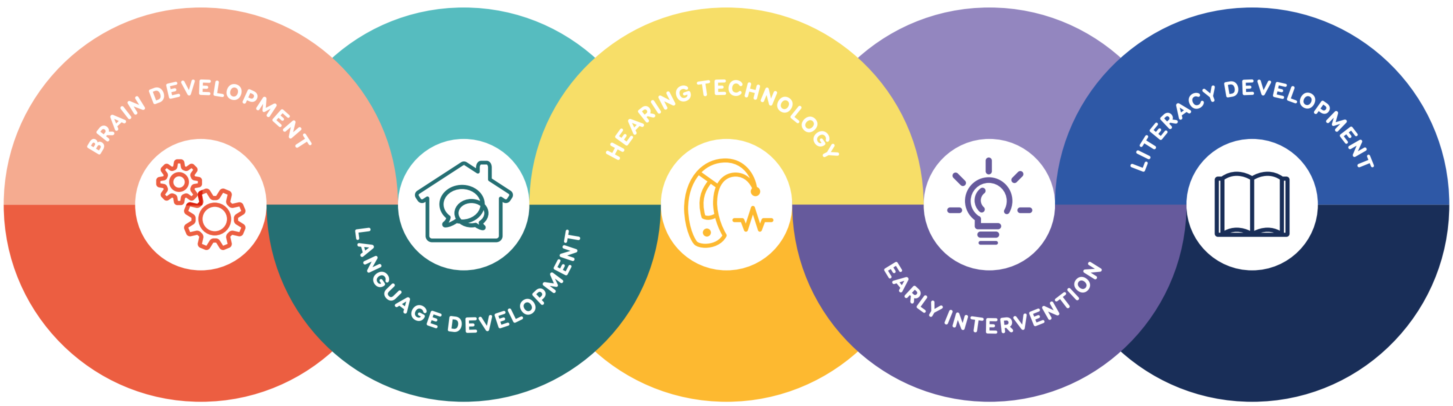
Summary of Listening and Spoken Language (LSL) Early Intervention for Literacy Development

Consistent with national education and literacy goals, our desired outcome is for all children who are deaf or hard of hearing to attain age-appropriate literacy skills by third grade along with their hearing friends. An early and solid neurological foundation in listening, spoken language and knowledge is needed to develop high levels of literacy.



Conclusion

Because of 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 multi-level 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 literacy outcomes consistent with hearing peers, IF we do what it takes. What it takes is system-wide attention to all links in the Logic Chain – no link can be skipped:



There continues to be a need for more studies to investigate the "literacy brain" of this new population. Does the brain of a child born with a closed auditory doorway (deaf), but who has early use of auditory technologies plus LSL parent-focused early intervention, look like the brain of a child with typical hearing? What supports might this child need to attain and remain on the trajectory to literacy?

As families explore intervention options and desired outcomes for their children, we need to provide them, continually, with the research and science we have collected as well as answers to the unknowns so they can make informed choices for their children and access the supports and services they need.

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