Achieving Age-appropriate Spoken Language and Literacy in Children Born with Hearing Loss:

It's Mission Probable When We Do What It Takes!

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INTRODUCTION

Children born with hearing loss are at risk of lifelong deficits in listening, spoken language, literacy, academic abilities. These deficits are a result of irreparable changes in the brain caused by insufficient stimulation of the auditory areas of the brain during the first two to three years of a child's life. In short, **childhood hearing loss is a neurodevelopmental emergency**, because when untreated, it leads to maladaptive changes in the brain that prevent the child from reaching her/his full potential. These alterations in brain development can lead to permanent deficits in spoken language and literacy abilities, which increase the likelihood the individual will require a long-term dependence on the social welfare system at a great cost to state and federal governments.

Fortunately, children born with any degree of hearing loss can achieve age-appropriate spoken language, literacy, and academic outcomes when hearing technology (e.g., hearing aids, cochlear implants, bone conduction devices) is provided within the first few months of life. In the United States, over 98% of infants receive a hearing screening at birth. This universal newborn hearing screening system allows for hearing loss to be identified early, and hearing technology to be provided promptly to ensure stimulation of the auditory areas of the brain and prevent the auditory deprivation that leads permanent alterations in brain development and the associated deficits in spoken language and academic outcomes.

This document provides an overview of the impact of childhood hearing loss with a focus on four areas: 1) the impact of childhood hearing loss on brain development, 2) the impact of childhood hearing loss on listening, spoken language, and literacy development, 3) the benefits of early access to hearing aids for children born with hearing loss, and 4) the financial benefits of providing proactive, auditory-based intervention for children born with hearing loss.

Figure 1. Only 1 in 10 California children have hearing aids covered by their commercial healthcare insurance plan.

THE IMPACT OF CHILDHOOD HEARING LOSS ON BRAIN DEVELOPMENT – IT'S A NEURODEVELOPMENTAL EMERGENCY!

The Auditory Brain

Auditory information is processed in the brain in an area called the auditory cortex, which resides in the temporal lobe of the brain (see Figures 2 and 3). The auditory cortex is roughly divided into two areas, the primary auditory cortex and the secondary auditory cortex The primary auditory cortex is clearly defined (see Figure 2), whereas the secondary cortex is less clearly defined but consists of an area that surrounds the primary auditory cortex like a belt (see Figure 3).

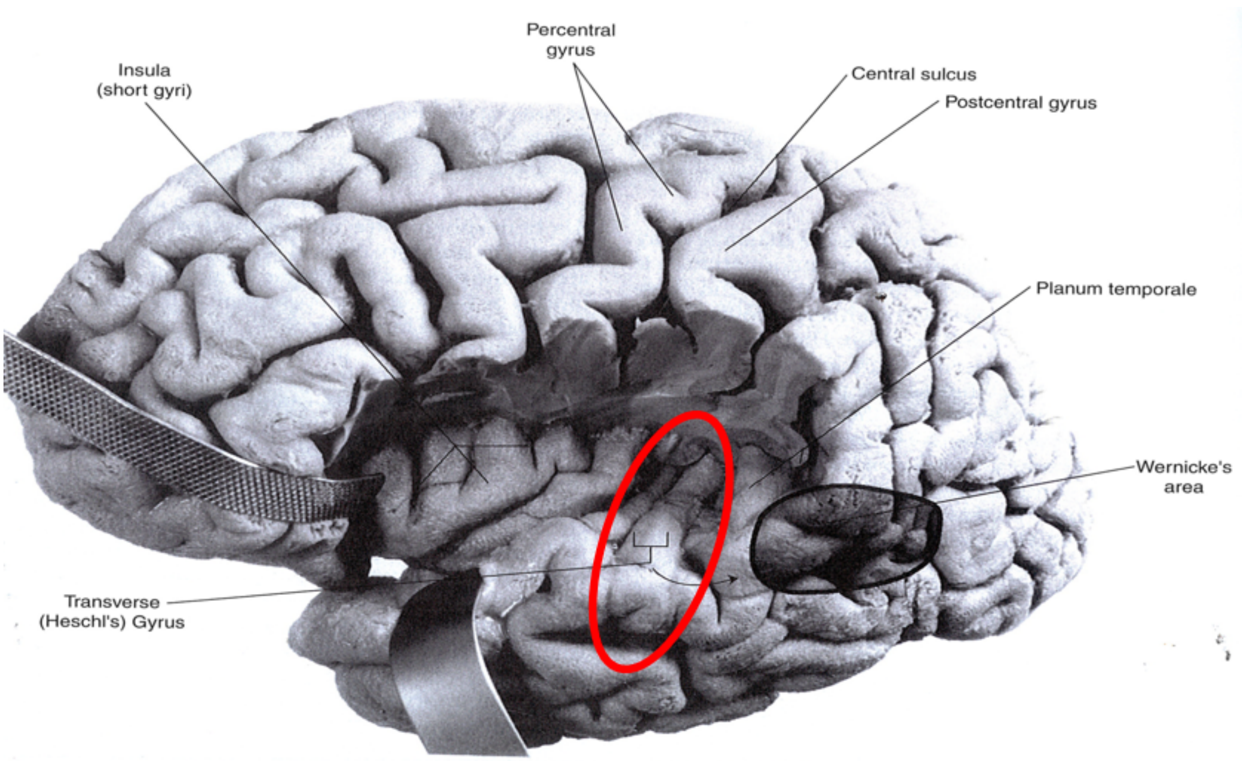


Figure 2. A visual depiction of the primary auditory cortex (i.e., Heschl's Gyrus marked by the **red oval;** Bhatnagar, 2013)

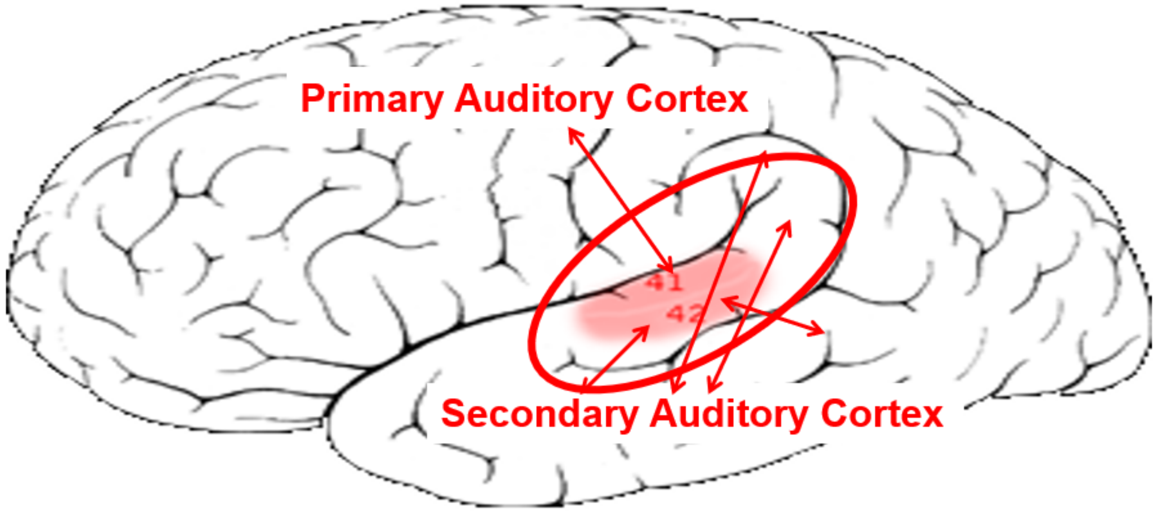


Figure 3. An illustration of the primary auditory cortex and the secondary auditory cortex (Bhatnagar, 2013).

In a grossly oversimplified description, the role of the primary auditory cortex is to detect sound and complete lower-level processing, whereas the secondary auditory cortex has a larger role in the comprehension of spoken language and processing the meaning of speech and environmental sounds. Additionally, the secondary auditory cortex communicates with other areas of the brain to create neural networks that support higher order processes such as:

- **Integration to Derive Higher-order Meaning:** Information from the auditory system must be shared with and processed by other functional areas of the brain, such as the visual system and the frontal lobe where critical thinking and processing occurs. This sharing of information between the auditory system and other areas of the brain is necessary for a sound to be perceived with its full meaning and richness.

- **Executive Function:** Broadly refers to the cognitive and behavioral processes that allow us to focus attention, remember and follow instructions or directions, and multi-task. Executive function supports planning and goal-driven behaviors. General examples include organizing a project at work or school, time management, self-awareness, etc. Executive function includes multiple components that are essential for successful navigation of daily functions:
    - **Working Memory:** The ability to be able to temporarily hold information and access it to complete cognitive tasks. Examples include being able to listen to a talker, store and comprehend the message, and respond appropriately.
    - **Self-regulation/Inhibitory Control:** The ability to control our automatic responses and urges (e.g., emotions, thoughts, behaviors, attention, etc.) so we can respond appropriately in daily situations. Examples include focusing attention on a project or task, preventing tantrums and meltdowns, avoiding making inappropriate remarks, staying in our seat during a boring meeting, etc.
    - **Sensory Integration:** The ability to process and organize sensory information received from each of the five senses in response to environmental stimulation and then respond with an appropriate action. Sensory integration is required to focus on the most relevant signal(s) of interest in an environment and "tune out" unimportant distractors.

It is important to note stress that early stimulation of the auditory areas of the brain influences the development of the higher-order processes described above. Figure 4 provides a visual description of the neural link between auditory stimulation and the creation of neural networks that allow for these higher-order functions.

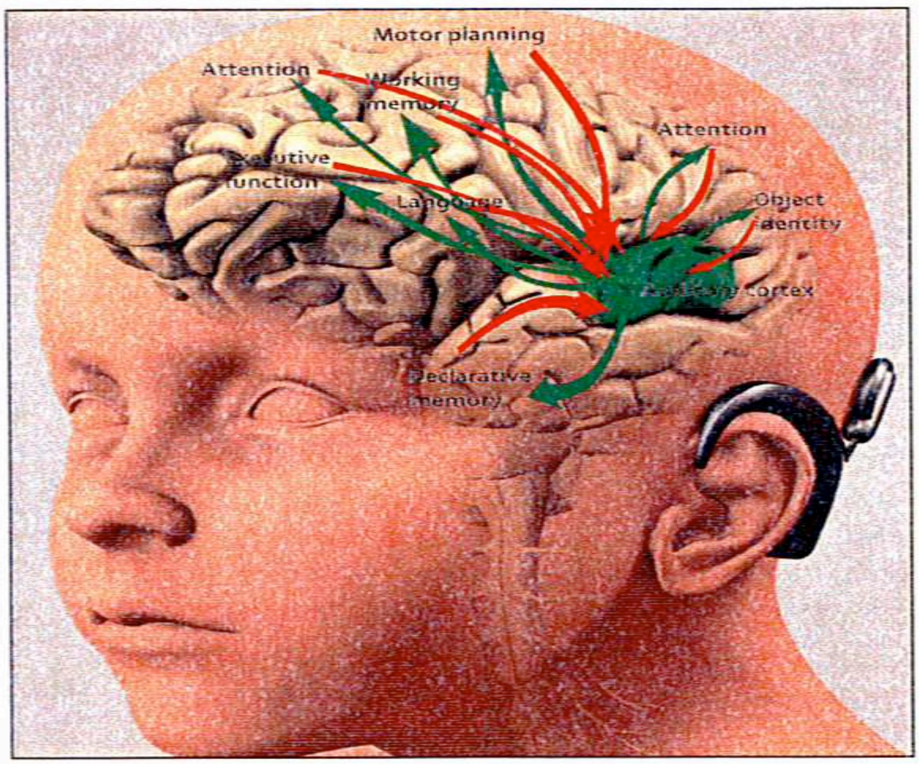


Figure 4. Illustration of the link between the auditory areas of the brain and the higher-order areas involved in various cognitive functions (Kral, 2016).

Please note that much of the interaction between the auditory area of the brain and the higher-order areas occurs at the secondary auditory cortex. In short, **the secondary auditory cortex serves as the gateway between the auditory areas of the brain and higher-order areas**.

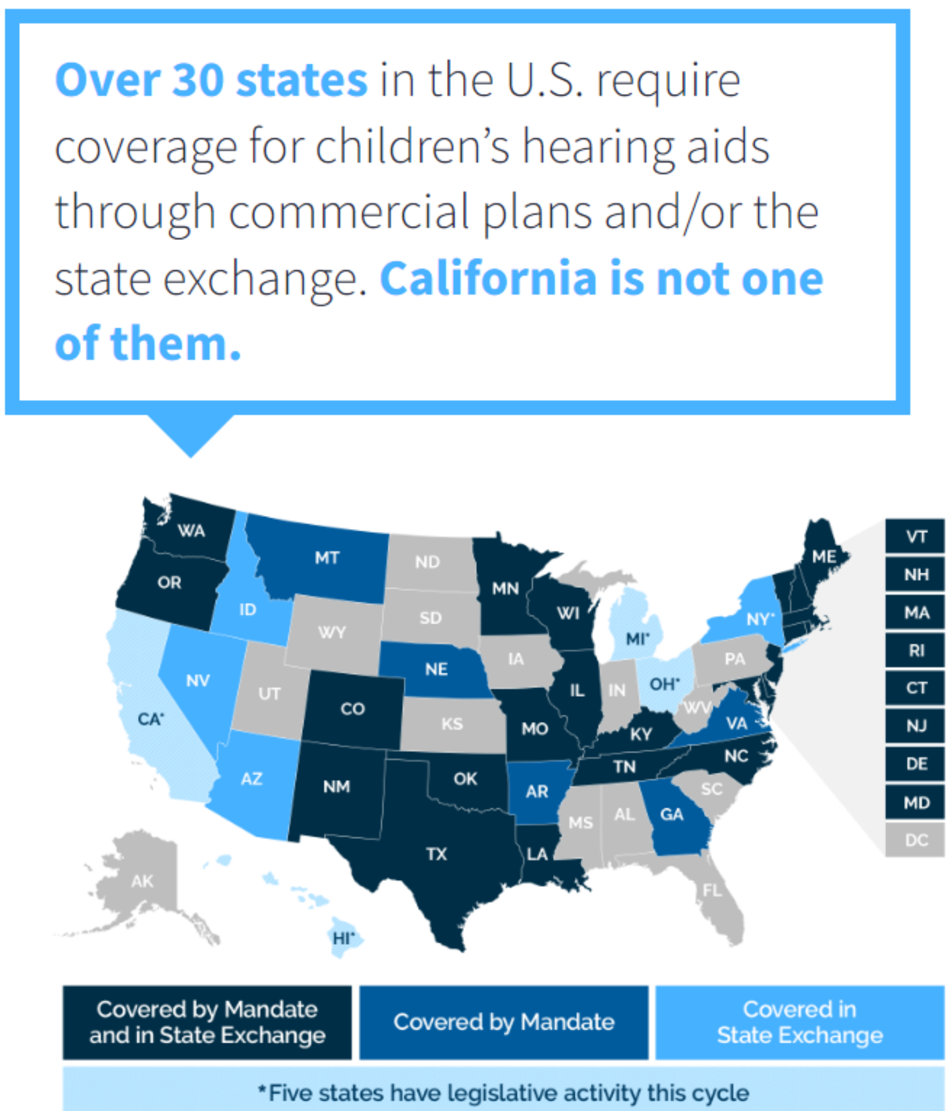


Figure 5. California sits with a minority of largely unprogressive states that do not require hearing aid coverage for children with hearing loss.

How The Brain Processes Speech

Figure 6 provides an example of stimulation in the brain of an adult who is listening to a story (Green, 2005). This adult was born with normal hearing, which allowed for normal auditory brain development. As shown in Figure 6, listening to the story results in broad stimulation of the auditory areas of the brain including activity in both the primary and secondary auditory cortices.

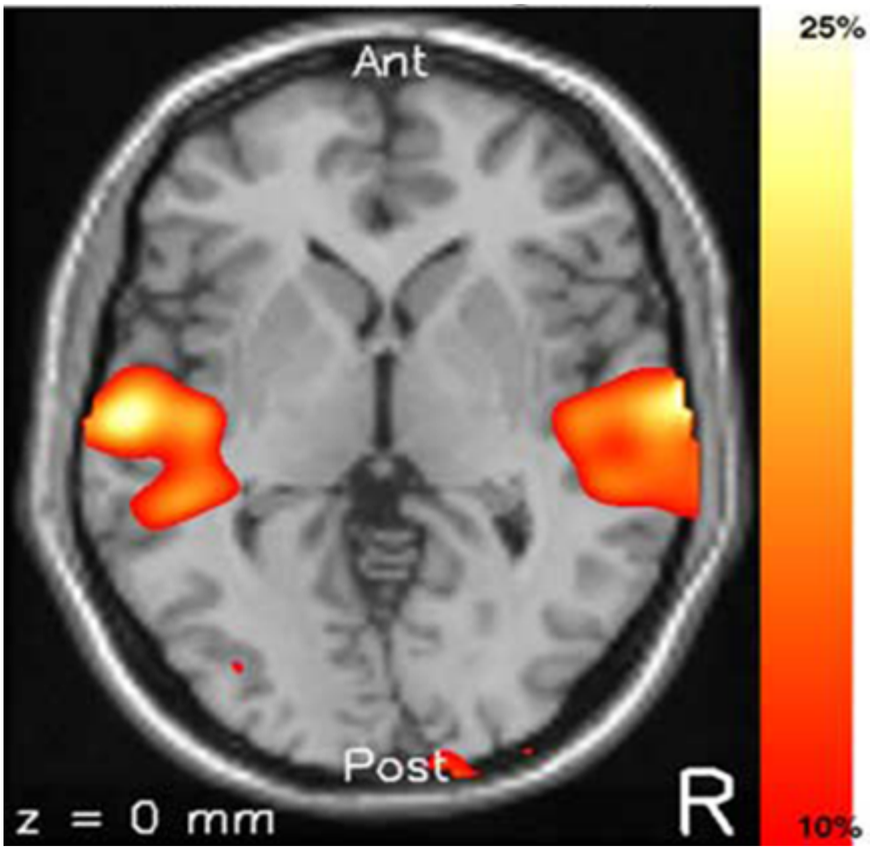


Figure 6. Listening to a story results in stimulation of the primary auditory cortex (shown in yellow) and the secondary auditory cortex (shown in orange and red) on both sides of the brain of an individual born with normal hearing (Green 2005).

It is important to note that the **activation of secondary auditory cortex in response to the talker's story allows for understanding of the spoken message as well as delivery of the message to other areas of the brain for higher-order processing that allows the message to be meaningful and allows the listener to act upon the message.**

The Impact of Under-treated Childhood Hearing Loss on Brain Development

Figure 7 provides a visual example of what occurs with brain development when a child is born with hearing loss and deprived of auditory stimulation throughout the first two to three years of life (an age range known as the ***critical period of language development***, because a child must hear during the first three years of life to develop typical listening and spoken language abilities). This individual learned to communicate through sign language and received a cochlear implant in adulthood after being almost entirely deprived of auditory stimulation of the brain (Nishimura et al., 2000).

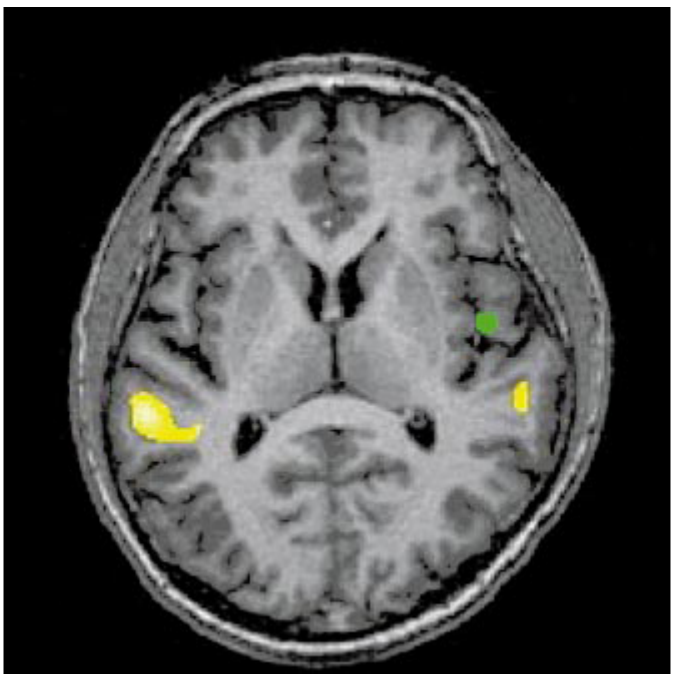


Figure 7. A visual example of stimulation of brain activity that occurs while listening to a story (shown in green) and while watching a story that is being told via sign language (shown in yellow) in the brain of an individual who was born with hearing loss and deprived of access to sound during early childhood (Nishimura et al., 2000).

As shown in Figure 7, when this individual listened to a story, brain activity was only present in the primary auditory cortex with no activity present in the secondary auditory cortex (**a finding referred to as a "decoupling" of primary and secondary auditory cortices**). Instead, watching the story told via sign language stimulated activity in the secondary auditory cortex. Consequently, **auditory stimulation in response to speech, music, and environmental sounds will contain little to no meaning and be largely incomprehensible for this individual.** Moreover, the auditory area of the brain will have weaker neural connections to higher-order areas of the brain, and typical neural networks will be disrupted and adversely affected. It is important to note that **these changes in brain function are largely permanent and will exist throughout life if hearing aids are not provided to children during the critical period of language development (first two to three years of life) to allow for typical auditory brain development.**

THE IMPACT OF CHILDHOOD HEARING LOSS ON LISTENING, SPOKEN LANGUAGE, AND LITERACY DEVELOPMENT – CHILDREN MUST HEAR TO LEARN TO SPEAK AND SOUND OUT WORDS TO READ

Impact of Under-treated Childhood Hearing Loss on Speech Understanding Abilities

When untreated childhood hearing loss results in alterations in brain development, significant deficits will occur in listening, spoken language, and literacy abilities. At the risk of stating the obvious, a listener must be able to hear speech to understand it. If a child does not adequately hear speech during the first two to three years of life, the changes that occur in the brain (as described above) will lead to lifelong difficulties in understanding speech. Figure 8 shows speech recognition scores for a group of 23 individuals who were born deaf and did not hear until receiving a cochlear implant during adolescence (de Souza et al., 2011). As shown, their ability to understand simple sentences spoken in quiet without visual cues was very poor after two years of cochlear implant use (i.e., mean score of 20% correct in the open-set sentence recognition condition).

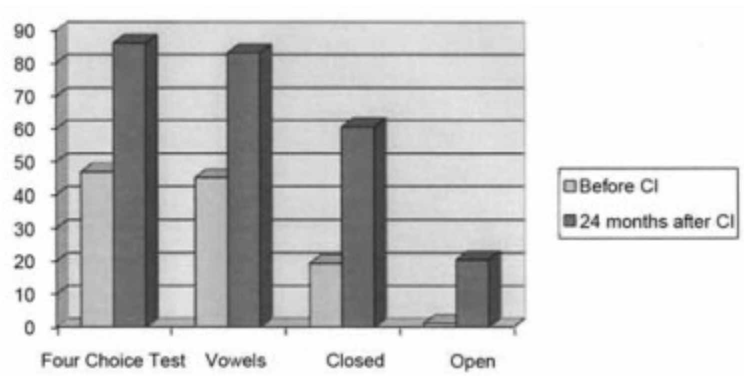


Figure 8. Speech recognition scores for children who were born deaf and did not have adequate auditory brain stimulation until receiving a cochlear implant in adolescence. Mean open-set sentence recognition is only 20% correct after two years of cochlear implant use (de Souza et al., 2011).

The poor speech understanding abilities of these children is due to the lack of access they had to intelligible speech during their first three years of life and the subsequent changes that occurred in the auditory areas of the brain (i.e., decoupling of the primary and secondary auditory cortices) and throughout the rest of the whole-brain neural network.

Impact of Under-treated Childhood Hearing Loss on Speech Production Abilities

Children who are born with hearing loss and who do not receive adequate auditory brain stimulation during the first few years of life also will experience long-term difficulties with the intelligible production of spoken language. Audition is required to provide the brain with the auditory feedback needed to learn how to position and move the lungs, larynx, mouth, tongue, teeth, and nasal cavity to produce clear speech. In an extreme case in which a child is born deaf and has no access to intelligible speech during the first few years of life, her/his own speech will most likely be severely impaired and possibly unintelligible for life. For children who are hard-of-hearing and do not receive hearing aids during the first few years of life, it is likely they will experience long-term struggles in their ability to clearly produce all the consonants in speech. For instance, they may omit or mispronounce consonant sounds such as /s/, /sh/, /t/, and /th/. Consequently, their speech will sound atypical and may be difficult to understand by individuals with normal hearing. Children's ability to speak is dependent upon their ability to hear. **When infants and young children cannot hear, they will not develop the ability to speak.**

Impact of Under-treated Childhood Hearing Loss on Spoken Language Abilities

Spoken language delays and deficits will also develop when children born with hearing loss do not have prompt access to intelligible speech and auditory stimulation of the brain. In a large National-Institute-of-Health-funded study of 228 children who were born with hearing loss and used hearing aids, the age at which children received their hearing aids was one of the most important factors affecting spoken language development with children who received hearing aids during infancy obtaining better spoken language outcomes (see Figure 9; Cupples et al., 2017).

Multiple regression summary table showing unstandardised coefficient estimates (*b*-values) and significance levels (*p*-values) of predictor variables for outcomes of children with hearing aids (*p*-values in parentheses).

	Outcome measure							
Predictor	*PLS-Rec*	*CDI-Rec*	*PPVT*	*PLS-Exp*	*CDI-Exp*	*PVC*	*PCC*	*PEACH*
(ln)AgeHA[ab]	5.14 (0.003)	−1.52 (0.04)	0.53 (0.07)	3.94 (0.01)	−12.15 (0.02)	−0.67 (0.02)	11.03 (0.03)	−3.25 (0.02)
4FAHL[c]	0.10 (<0.001)	−0.15 (0.08)	−0.20 (<0.001)	0.05 (<0.001)	−0.57 (0.10)	0.02 (0.34)	0.31 (0.001)	−0.13 (0.34)
(ln)AgeHA[a] × 4FAHL	−0.18 (0.05)	−0.05 (0.69)	−0.06 (0.43)	−0.14 (0.10)	0.15 (0.29)	−0.05 (0.54)	−0.26 (0.02)	0.00 (0.97)
WNV	0.85 (<0.001)	0.62 (<0.001)	0.65 (<0.001)	0.68 (<0.001)	0.65 (<0.001)	0.49 (<0.001)	0.64 (<0.001)	0.28 (<0.001)
Gender[d]	2.67 (0.30)	−2.23 (0.44)	1.49 (0.53)	3.41 (0.15)	−1.41 (0.69)	0.76 (0.75)	2.72 (0.36)	−1.12 (0.61)
ADisab	−3.10 (0.32)	−5.34 (0.12)	−3.00 (0.33)	−3.91 (0.18)	−8.82 (0.04)	−2.44 (0.42)	−12.13 (0.002)	−3.96 (0.14)
MatEd[e]	10.75, 9.95 (0.002)	13.86, 13.41 (<0.001)	9.81, 9.12 (0.001)	9.34, 9.05 (0.003)	15.02, 14.95 (0.001)	6.07, 5.65 (0.07)	10.76, 11.46 (0.003)	1.25, 8.02 (0.004)
Mode[f]	−8.31, −9.49 (0.004)	−1.44, −5.03 (0.44)	−10.43, −10.65 (<0.001)	−6.74, −7.63 (0.02)	−4.04, −5.02 (0.54)	−4.59, −7.19 (0.07)	−7.43, −9.15 (0.05)	−1.23, 1.81 (0.74)
Sample size	223	167	224	224	167	225	226	168
Adjusted R^2	0.70	0.56	0.64	0.63	0.51	0.45	0.56	0.30

Figure 9. Factors influencing language outcomes of children who were born deaf and who use hearing aids. Of note, the age at which the children received their hearing aids significantly impacted their language development (Cupples et al., 2017).

Impact of Under-treated Childhood Hearing Loss on Reading Abilities

The potential to develop optimal reading abilities is also inextricably linked to good hearing and auditory stimulation of the brain during the first few years of life. **Children who are born deaf, do not develop listening and spoken language skills, and graduate from a residential school for Deaf children who communicate via sign language have historically read at a 2nd to 4th grade level upon graduation of high school** (Easterbrooks & Beal-Alvarez, 2012; Easterbrooks et al., 2015; Traxler, 2000). Literacy development is dependent upon the attainment of phonemic awareness, which is an understanding of the letter and sound relationship. For instance, children must understand that the "A" says "ah," the "B" says "buh," and the "C" says "cee." Phonemic awareness is necessary to sound out words and "crack the literacy code." **Children must be able to hear all the sounds (i.e., phonemes) of speech to develop phonemic awareness.** Of note, neuroimaging studies have indicated that the areas of the brain that are active during listening and spoken language are also the same areas of the brain that are active during reading. If children born with hearing loss do not have prompt access to hearing aids and are deprived of auditory stimulation of the brain during the first two to three years of life, phonemic awareness deficits will occur and will be accompanied by reading disorders. Not surprisingly, reading delays or deficits in young children jeopardize their success across all academic domains. Furthermore**, poor reading abilities limit vocational opportunities after graduation, especially in our technology-driven world in which communication often occurs through the written word.**

Impact of Under-treated Childhood Hearing Loss on Higher-Order Processes and Abilities

It should also be noted that childhood hearing loss can also lead to significant deficits in higher-order processes when the auditory areas of the brain do not receive adequate stimulation during the first two to three years of life, and language is delayed. Indeed, **research has shown children born with hearing loss have historically experienced abnormal executive function skills due to insufficient stimulation of the auditory areas of the brain and poor language abilities** (Conway et al., 2009; Nittrouer et al., 2017).

THE BENEFITS OF EARLY ACCESS TO HEARING AIDS FOR CHILDREN WITH HEARING LOSS: MISSION PROBABLE!

Advances in hearing technology and pediatric hearing healthcare have created substantial opportunities for children born with hearing loss. In fact, **age-appropriate listening, spoken language, and literacy skills are not just possible for children with hearing loss, but instead are probable when evidence-based, audition-focused intervention is provided as soon as a child's hearing loss is identified.** Universal newborn hearing screening has allowed for identification of hearing loss during the first one to three months of life. When hearing loss is identified, hearing aids can and should be fitted in the first few months of life. For children with severe to profound hearing loss, cochlear implantation can and should be provided during the first six to 12 months of a child's life when the family desires for the child to develop optimal listening and spoken language abilities. When hearing aids and cochlear implants are promptly provided and consistently used by children with hearing loss, age-appropriate spoken language and literacy outcomes are expected to occur.

The Benefit of Hearing Aid Use for Speech Understanding

Consistent use of hearing during the first few years of life allows children who are born hard-of-hearing to develop excellent open-set speech understanding abilities. As shown in Figure 10, a large study of over 300 school-age children who were hard-of-hearing found mean open-set speech understanding scores approaching 90% correct and in close proximity to their age-matched peers with normal hearing (McCreery et al., 2015).

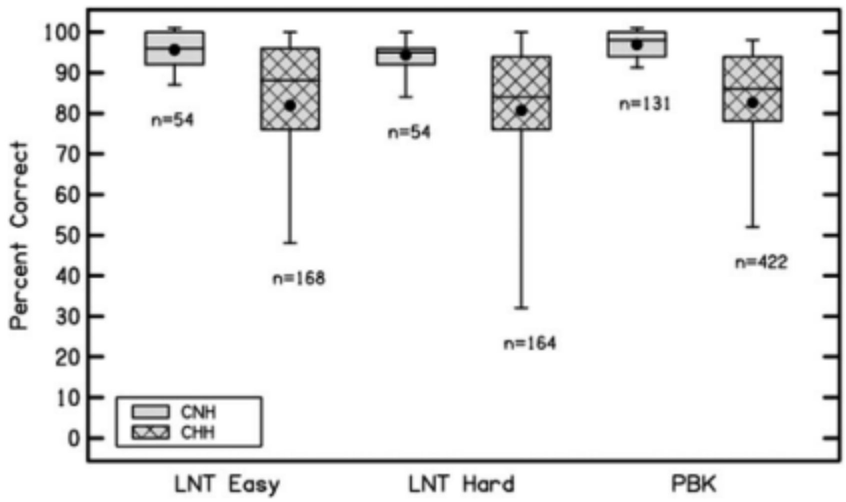


Figure 10. Mean speech understanding scores for children with normal hearing (CNH) and children who are hard-of-hearing and use hearing aids (CHH; McCreery et al., 2015).

Figure 11 provides an illustration of the importance of hearing aid use for children born with hearing loss. As shown, better language abilities are associated with a greater amount of audible speech provided by the hearing aid.

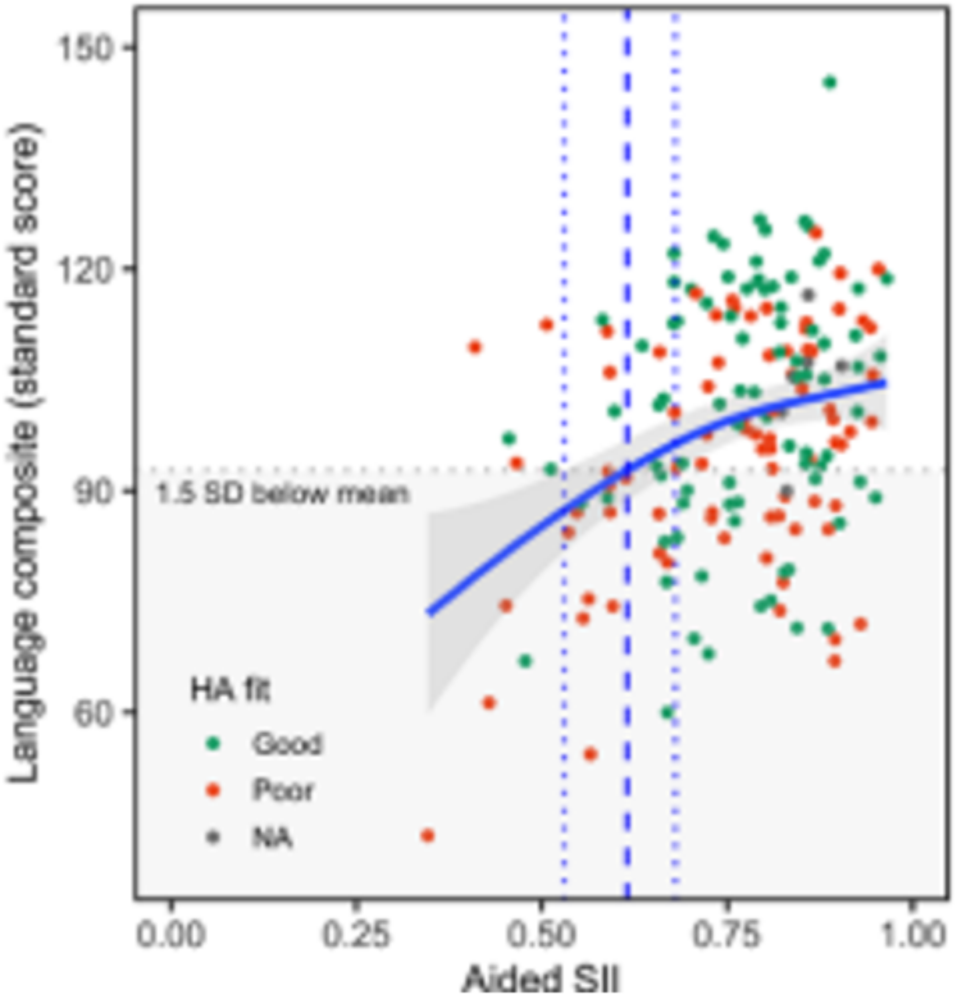
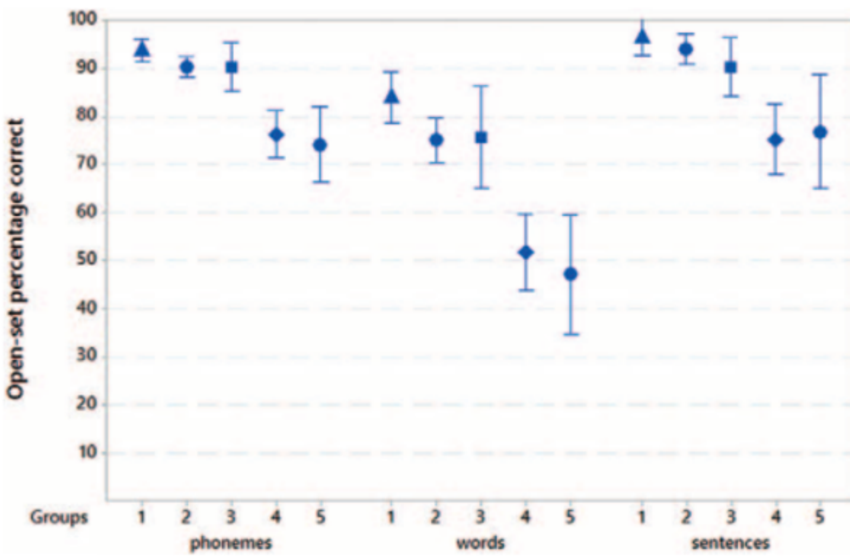


Figure 11. The spoken language abilities of children with hearing loss improve with greater access to amplified speech provided by hearing aids (Wiseman et al., 2022)

Of note, the effect of age of intervention is also an important factor for children who receive cochlear implants. As shown in Figure 12, speech understanding is significantly better for children who have earlier access to intelligible speech and auditory stimulation of the brain, with the best outcomes achieved by children who receive their cochlear implant prior to 12 months of age. Once again, the children who received early access to intelligible speech and auditory stimulation of the brain achieved mean open-set speech understanding scores without visual cues approaching or exceeding 90% correct. **Taken collectively, the data shown in Figures 10, 11, and 12 demonstrate that excellent speech understanding abilities are probable for children with hearing loss when they receive hearing technology at an early age.**



Open-set (audition alone) word, phoneme, and sentence percentage accuracy for n = 81 at late primary/early secondary school, Groups 1–5.

Age at CI
1: <12mths
2: 13-18mths
3: 19-24mths
4: 25-42mths
5: 43-72mths

Figure 12. Open-set speech recognition scores as a function of age at which the child received a cochlear implant.

The Benefit of Hearing Aid Use on Spoken Language Development

Early access to hearing aids and cochlear implants allows for auditory stimulation of the brain which is also imperative to allow for age-appropriate spoken language development in children with hearing loss. In a landmark study with more than 400 children with hearing loss, children who were fitted with hearing aids prior to six month of age achieved age-appropriate spoken language outcomes that were commensurate with normal levels for children with normal hearing and were better than the language outcomes of children fitted with hearing aids after six months of age (see Figure 13, Tomblin et al., 2015). Of note, over time, children fitted with hearing aids after six months of age partially caught up with the language outcomes of those fitted prior to six months of age. However, it should be noted that a much greater amount of early intervention and therapy is required to mitigate these early language delays. **When hearing aids are fitted in the first few months of life, children born with hearing loss typically never fall behind, because they receive consistent stimulation of the auditory areas of the brain throughout the critical period of language development.**

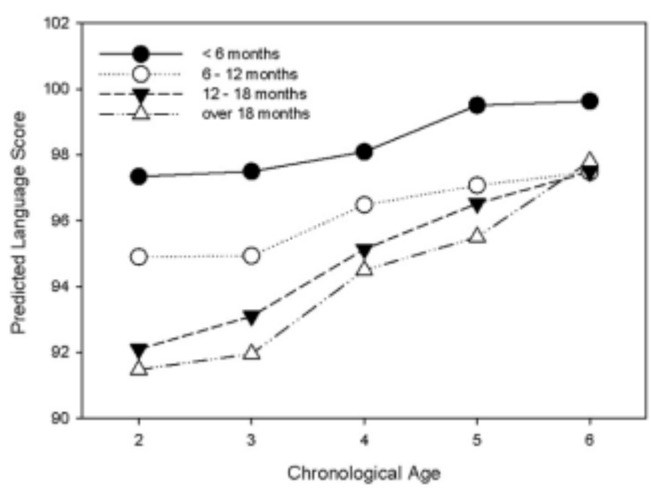


Figure 13. Mean spoken language scores for children fitted with hearing aids at different ages.

The effect of early access to intelligible speech and auditory stimulation of the brain is also very prominent in children who use cochlear implants. As shown in Figure 14, the spoken language scores of children with cochlear implants are significantly better when the cochlear implant is provided during the first year of life.

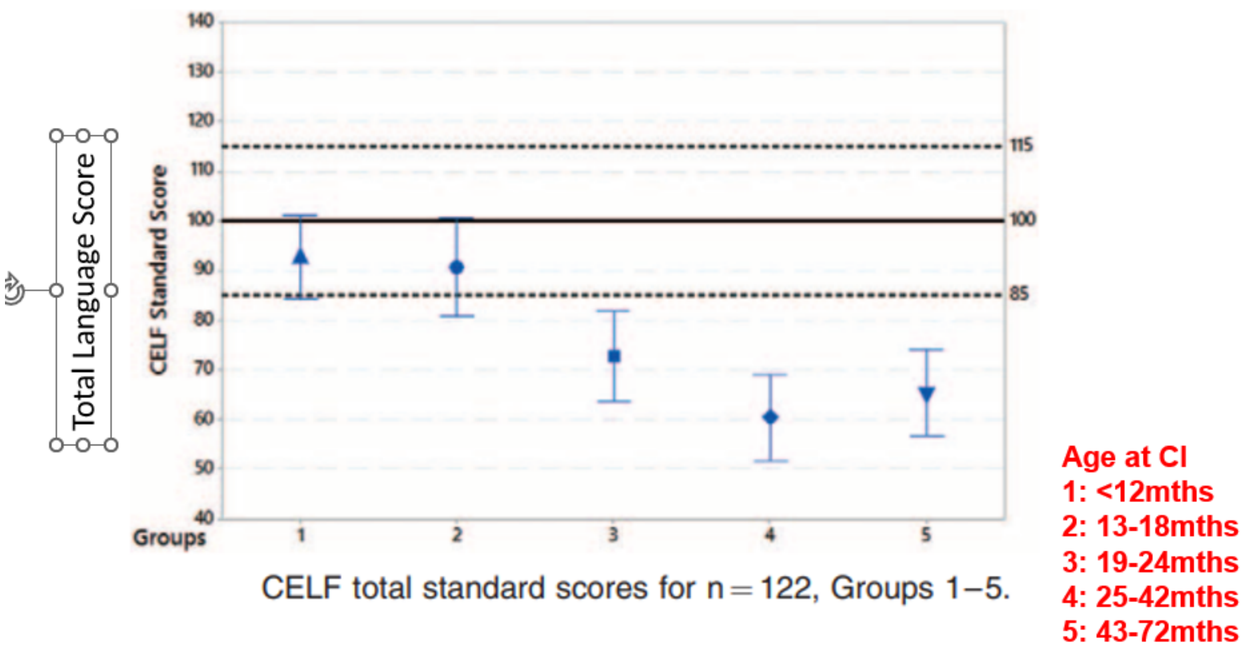


Figure 14. Mean spoken language scores for children fitted cochlear implants at different ages.

Yet again, it should be noted that **the data shown in Figures 13 and 14 demonstrate that excellent spoken language abilities should be expected for children with hearing loss when they receive hearing technology at an early age. Additionally, prompt provision of hearing aids and cochlear implants typically prevent children from hearing loss from developing spoken language delays, which reduces or eliminates the need for costly therapies and educational supports later in life.**

A recent study with children who were born hard-of-hearing and who have used hearing aids since an early age found elementary reading levels to be on par with their peers with normal hearing (see Figure 15, Walker et al., 2020).

	MBHL	NH	Between groups	
Outcome variable	*M (SD)*	*M (SD)*	*d*	*p*
WJTA Picture Vocabulary SS	99.78 (10.76)	103.06 (10.11)	0.31	.077
WJTA Understanding Directions SS	97.59 (12.64)	104.70 (12.59)	0.56	.002*
Test of Morphological Awareness raw score	16.64 (5.27)	18.84 (4.78)	0.44	.015*
GORT Oral Reading Index SS	93.36 (13.58)	94.91 (12.25)	0.12	.497

Note. WJTA = Woodcock-Johnson Tests of Achievement; SS = standard score; GORT = Gray Oral Reading Tests.
*Significance with α level = .05.

Figure 15. Language and literacy scores of children who are hard-of-hearing and hearing aids users and children who have normal hearing (Walker et al., 2020).

The Benefit of Hearing Aid Use on Reading Development

Additional studies examining the reading outcomes of children who are born with hearing loss and who receive hearing aids and cochlear implants at an early age have also found age-appropriate literacy outcomes that far exceed the outcomes children with hearing loss achieved prior to the availability of early intervention and early provision of hearing aids and cochlear implants (Geers & Hayes, 2011; Geers & Warner-Czyz, 2017; Wass et al., 2019). **With early provision of hearing aids and cochlear implants, children with hearing loss can develop age-appropriate reading abilities that position them to succeed in the classroom and eventually as a tax-paying citizen in the workforce.**

The Benefit of Hearing Aid Use on Higher Order Processes and Abilities

Early access to hearing aids and cochlear implants provides auditory stimulation to the brain and also supports typical development of higher-order processes such as executive function and working memory. For instance, McCreery and Walker (2022) recently found that the executive function abilities of children who are hard-of-hearing improve and typically approach normal limits with greater hours of hearing aid use. Additionally, Heinrichs-Graham and colleagues (2022) studied neural oscillatory behavior in the brains of children with hearing loss and found that neural activity underlying verbal working memory was better for children with more hearing aid use and was similar to that of children with normal hearing for children who used hearing aids for most waking hours since early childhood (see Figure 16).

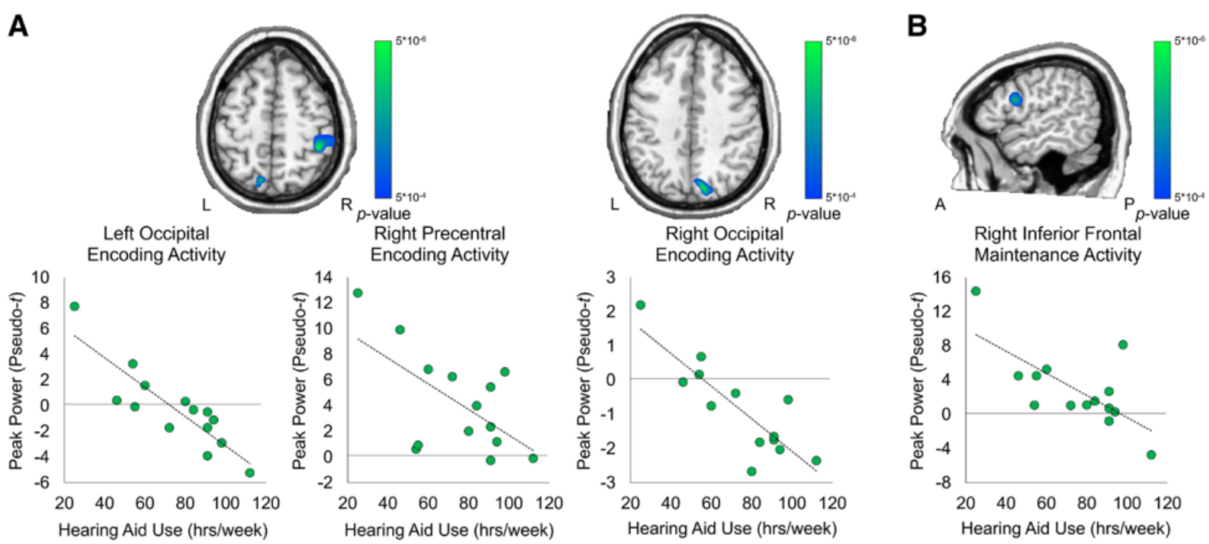


Figure 16. Neural oscillatory behavior of children with hearing loss as a function of hearing aid use (Heinrichs-Graham et al., 2022).

Higher-order processes, such as executive function, working memory, self-regulation, and sensory integration are inextricably linked to auditory brain development and language abilities. **Research has shown that these higher-order processes (e.g., executive function, working memory, etc.) are likely to approach normal limits for children with hearing loss when hearing aids and cochlear are provided at an early age.**

THE FINANCIAL BENEFITS OF AUDITORY INTERVENTION FOR CHILDREN BORN WITH HEARING LOSS: THE BOTTOM LINE $4 MILLION RETURN!

Researchers and economists have long recognized that childhood hearing loss creates a large financial burden on society when children do not have access to hearing aids and cochlear implants. In 2000, a research study estimated a societal cost of almost $1 million for each child who is born with hearing loss and who does not have early access to hearing aids or cochlear implants (Mohr et al., 2000). Adjusted for inflation, the 2000 study estimate corresponds to a cost for untreated newborn hearing loss of $1.8 million in 2023 (Bureau of Labor Statistics, 2023).

The societal costs per child may actually exceed the $1.8 million estimate when one factors in additional costs associated with specialized education and social welfare supports commonly required for children who are born with hearing loss and who do not develop functional listening and spoken language. The following description provides an itemized estimate of the lifetime costs associated with childhood deafness when spoken language and literacy deficits exist secondary to hearing loss.

- Children who are born deaf and who do not receive hearing aids or cochlear implants during the first two to three years of life often do not develop the ability to listen and communicate via spoken language.
- Children who have hearing loss and are unable to communicate via spoken language typically must rely on the use of sign language for communication.
- Children who communicate primarily via sign language often attend residential schools for children who are deaf in order to receive special education customized to meet the needs of children who communicate via sign language.
- In California, the per-student cost to provide education at a residential school for children who are deaf is approximately $120,000, annually. Over 13 years of education (i.e., kindergarten through 12th grade), the cost to educate each child at a residential school for children who are deaf is approximately $1.56 million dollars (i.e., 13 years of education * $120,000 per year).
- The per-student cost to provide a typical public school education in California is approximately $14,000, annually for a total cost of approximately $182,000 per student (i.e., 13 years of education * $14,000 per year).
- As previously noted, research has indicated that the typical high school graduate of a residential school for children who are deaf has a 2nd to 4th grade reading level.
- Poor reading and spoken language skills often limit employment options after graduation from a school for children who are deaf, and as a result, many are dependent on the social welfare system.

- The cost of government-funded social welfare for a family of four is approximately $60,000, annually.
- Over the course of a 40-year professional career, the cost to provide social welfare for a family of four is approximately $2.4 million (40 years * $60,000, annually).
- Individuals who rely on the social welfare system pay little to no income tax.
- The average Californian pays approximately $16,000 in taxes, annually.
- For underemployed Californians who do not pay taxes, the government loses approximately $640,000 in lost income from taxes typically paid by Californian citizens (40 years * $16,000, annually.
- Collectively, the cost of education, the provision of social welfare, and lost income taxes totals approximately $4.5 million over the life of an individual born who is born with hearing loss and does not develop functional spoken language and literacy skills ($1.56 million + $2.4 million + $640,000 = $4.6 million).
- Two hearing aids may be acquired at a total cost of approximately $1000-$2000 for children with hearing loss.
- Most children with hearing loss require replacement of their hearing aids every three to five years, which means four to six sets of hearing aids are typically required between the ages of birth to 18 years of age for a total cost of no more than $12,000.
- The total cost of supporting two cochlear implant systems for a child between birth to 18 years of age is approximately $100,000 to $125,000.

- Most children who receive appropriate hearing technology and support can develop age-appropriate spoken language and literacy abilities, and as a result, they can become tax-paying citizens who are not reliant on the social welfare system.
- When children with hearing loss receive appropriate hearing technology and develop typical spoken language and literacy abilities, the societal cost to support childhood hearing healthcare and public education is approximately $200,000 to $300,000 (i.e., cost of 13 years of public education and hearing aids or cochlear implants from birth to 18 years of age).
- To summarize, investing in hearing technology (e.g., hearing aids, cochlear implants, etc.) for children with hearing loss results in a potential savings of almost $4 million dollars to society.

CONCLUSIONS

1. Childhood hearing loss can alter brain development, which can lead to lifelong changes in brain function.
2. Childhood hearing loss is a neurodevelopmental emergency!
3. Childhood hearing loss and the associated changes in brain development can lead to lifelong deficits in spoken language, literacy, and cognitive abilities.
4. Lifelong deficits in spoken language, literacy, and cognitive abilities can create a lifelong dependence on the social welfare system.
5. In 2023, the societal cost of undertreated childhood hearing loss ranges from $1.8 million to $4.5 million.

6. Immediate provision and use of hearing aids and cochlear implants can allow typical brain development to occur for children with any degree of hearing loss.
7. With immediate and consistent use of hearing aids and cochlear implants, children with any degree of hearing loss are likely to develop age-appropriate spoken language, literacy, and cognitive abilities.
8. Children who have hearing loss and age-appropriate spoken language, literacy, and cognitive skills are not dependent on the social welfare system, and instead, become tax-paying citizens.
9. The cost of providing hearing aids and cochlear implants plus a public-school education in California from birth to 18 years of age is approximately $200,000 to $300,000.
10. Mandating healthcare coverage of hearing aids and cochlear implants for children with hearing loss can save up to $4 million for the state of California over the lifetime of a child born with hearing loss.