REVIEW
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# Language Intervention Instead of Speech Intervention for Children With Cochlear Implants

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Cochlear implants are a standard rehabilitation option for children with severe hearing loss or deafness, allowing access to speech sounds necessary for the development of spoken language. However, the speech–language outcomes of pediatric cochlear implant users vary widely and are not directly or exclusively linked to technology but to combinations of individual audiological, personal, technical, and habilitational factors. These combinations may not favor spoken language development, which may further be linked to the issue of prior insistence on spoken language learning and associated with a high risk of language deprivation. Here, we discuss the outcomes of cochlear implantation from a habilitative perspective and lay down the efforts and resources necessary for the development of communication competence after cochlear implantation rather than the achievement of specific hearing, language, or speech skills that have limited socioemotional and educational contributions and do not guarantee an independent or productive life. **J Audiol Otol 2023;27(2):55-62**

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## Introduction

Owing to the constant increase in the already large population of deaf and hard-of-hearing people (DHH) [1], cochlear implant (CI) technology is constantly improving. Hence, modern devices of this type enable the audibility of the entire speech spectrum which implies great potential for spoken language development or conservation [2]. Continuous efforts to improve CI performances resulted in the rise of this technology to the status of the most successful implantable device in modern medicine [3]: as of December 2019, approximately 736,900 registered devices have been implanted worldwide [4].

In some cases, CIs enable spoken language, literacy, and educational development consistent with hearing peers [2,5,6]. In adults [7-9] and elderly adults [10,11] with postlingual hearing loss, the potential of CIs is reflected in the improvements in quality of life. For the wide use and further development of this technology, an important illustration of its success is 9,000 to even 40,000 US dollars worth of annual gains in quality of life per patient [12], mostly due to improvements in employment and job retention.

Candidates for cochlear implantation are people with severe-to-profound or higher degrees of sensorineural hearing loss, who do not benefit from classical hearing aids, have good general health and psychosocial status, and have no structural obstructive findings in the auditory pathway. The rapid development of this technology and the positive outcomes of implantation constantly contribute to lowering the preoperative criteria; therefore, recently, people with lower pure tone thresholds, more favorable aided speech perception, and unilateral deafness have been implanted [13].

Emphasis on the positive side of CI technology can lead to the conclusion of its universal (re)habilitation success, but this conclusion is biased, considering the abundance of evidence of significant variability in its outcomes. Postlingually implanted persons obtain hearing functionality that positively affects their quality of life, and there is no doubt that this technology is a valuable solution for most individuals with postlingual sensorineural hearing loss who do not benefit from classical hearing aids. However, this technology still cannot uniformly compensate for the consequences of congenital or early acquired hearing loss on the development of listening, communication, language, speech, cognition, and, ultimately, academic achievement.

Given the documented coexistence of excellent pre-implantation characteristics and subsequent poor language and speech outcomes [14], the variable success of CIs in a population with prelingual hearing loss should be viewed through the prism of the complex inter-relationships of several important factors [15]. A fact that is often (opportunely) overlooked is that the brain stimulation provided by a CI is by no means the same—or even very similar—to that provided to the brain by the hearing ear: in comparison, it is incomplete, degraded and for some users clearly insufficient for speech development [16,17]. However, some pediatric CI users manage to utilize this receptive, “raw material” to achieve spoken language outcomes in line with their peers. The question of why such variability occurs despite equal entry characteristics and early interventions remains open. The aim of this study is to highlight the factors so far identified as important for spoken language outcomes in pediatric CI users. In the paper, the CI technology is viewed ecologically and multidimensionally, considering overall impact of this technology on communication and subsequent quality of life, and not only on listening, language, and speech development, as it is often the case [18]. This aim was set in accordance with empirical evidence of the romanticization [19] of CI technology as a universal and optimal solution [20], which prevents the realization of: 1) its real current reach in the delivery of a quality signal to the auditory centers in the brain, and 2) the importance of non-technical aspects of the intervention, which is reduced by the non-objective presentation of this technology [21].

## Predictors of Cochlear Implantation Outcome in the Pediatric Population Identified So Far

The greatest potential near-peer receptive and expressive language development is generally associated with very early cochlear implantation [22-31]—at the age of up to 4 years of life, in the period of the greatest plasticity of the central nervous system [32]. Only early, continuous, and rich stimulation of the auditory pathway promotes the development of auditory centers in the brain, and without it, it is impossible to expect the brain to develop all the resources necessary for speech communication [33,34]. The earliest possible stimulation of auditory centers creates a direct neurophysiological possibility for the development of perceptual abilities that precede learning to listen to speech, which is the basis of learning spoken language, reading, writing, and learning in general [2]. The exploitation of neural plasticity by stimulating the auditory centers with CIs implies their use during all waking hours [35,36]. The number of hours of daily use of CIs and the duration of their use from the point of implantation are also important factors in language and speech outcomes in the pediatric population.

Increasingly advanced speech processing strategies that deliver signals to the auditory nerve through a greater number of active electrodes with a better dynamic range favor more successful hearing, language, and speech development [37-39]. Therefore, the success of CI technology is logically connected with expert performance management of these devices, that is, the programming of their processors according to the specific needs of individual users.

The literature suggests that optimal habilitation after cochlear implantation is oriented towards abundant spoken language stimulation [23,40], facilitated through continuous guidance and training of family members by a team of experts [41]. Specific personal and environmental factors—gender, nonverbal IQ, affinity for listening and oral language development, and family educational and socioeconomic characteristics—may also play an important role in the final outcomes of cochlear implantation [17,42,43].

## Neurocognitive Studies of Cochlear Implantation Outcomes in the Pediatric Population

The aforementioned factors have limited predictability [44], so recent research has focused on the search for additional factors that could explain the variability in the language outcomes of pediatric CI users [45]: the neurobiological and neurocognitive aspects of spoken language learning. According to the “neurocognitive theory,” some pediatric CI users cannot compensate for the absence of the earliest stimulation of the auditory centers in the brain, and even after early cochlear implantation show weaknesses in the development of sensory coding and corresponding language processing skills of speech sounds provided by the device. This theory highlights specifics in the neurocognitive development of children with a CI (more precisely, in verbal working memory), caused by the absence of listening in the months before implantation and consequential failure in learning the time-sequential features of speech sounds [45-47]. Neurocognitive theory points out that auditory deprivation that precedes early cochlear implantation hinders some pediatric CI users in the development of cognitive functions necessary for language processing, such as learning to recognize a series of sounds in which words are made up (i.e., in the development of phonological awareness).

However, "sensory theory" emphasizes the still insufficiently reliable quality of the sounds delivered to the auditory centers in the brain by the implanted device. This theory also focuses on verbal working memory [48], but from the perspective of difficulties in learning the correct phonological codes and consequent weaknesses in the development of phonological awareness due to the degraded signal that arrives for processing [16]. This enables the coexistence of minor lexical and major phonological difficulties in the language of children who use CIs. Therefore, due to the inability of speech signal processors in CIs to faithfully transmit all the acoustic features of speech, mental representations of speech sounds are not formed correctly, which negatively affects the further language development [49].

Further research focused more closely on the working memory model [48] to gather evidence for a stronger argumentation of one or the other mentioned theory. In this regard, some authors state that non-verbal (visuo-spatial) working memory in pediatric CI users also appears to be inferior compared to their hearing peers [44,46,50,51], which is considered a potential predictor of the variance in their language outcomes. However, other studies suggest that the effects of early auditory deprivation and poor signal resolution provided by CIs are reflected differently in verbal and non-verbal working memory. Some authors report that weak working memory skills, even with good audibility, first refer to the verbal aspect (coding, storage, and manipulation of verbal information), while in the visuo-spatial aspect (storage and manipulation of non-verbal information), pediatric CI users demonstrate skills consistent with their peers [52,53]. Therefore, it is possible that the different organization of working memory in children with CIs is not actually an exclusive consequence of early hearing deprivation, but that in its verbal component, it results from difficulties with the coding of speech sounds, and in the non-verbal component from the verbal mediation of visual information whose processing is being observed (e.g., verbal encoding of numbers or colors in working memory tasks). When this mediation is avoided, the performance of children with CIs on non-verbal tasks improves [52]. In simpler terms, research on the non-verbal working memory of children with CI has shown that they have the same cognitive potential as their hearing peers if there is no verbal mediation in the working memory tasks, which undermines the cognitive theory of a specific brain architecture due to early auditory deprivation and contributes to the sensory theory about the still insufficient resolution of speech sound provided by the CIs. It seems that early hearing deprivation does not generally affect the cognitive potential of children with CIs, but in relation to their hearing peers, they achieve poor results only on cognitive tasks that are verbally saturated or indirectly rely on verbal skills, which is a consequence of technology that does not provide sufficient resolution for spoken language learning; if the verbal aspect is excluded from cognitive tasks, the performance of children with CIs becomes comparable to that of their hearing peers [52,54,55].

Working memory is a constitutive part of so-called executive function—higher cognitive processes necessary for directing, organizing and self-controlling behavior [56]—which was also marked as inferior in children with CI to one of their hearing peers, and language skills seem to be a mediating factor for cognitive functionality, but not vice versa (poor results of executive function tests did not lead to poorer language skills) [57]. This indicates that prelingual hearing impairments do not affect cognitive architecture per se, but higher cognitive mechanisms are formed in accordance with the received stimulation during development [58]. In other words, brain plasticity has an experiential basis [59], so the organizational and functional specifics of its development depend on the stimulation it is exposed to. Therefore, along with parental bonding, attention-getting strategies, socio-cognitive development, and other stimuli [60], a crucial element for brain development is exposure to quality linguistic stimulation [61].

## Practical Considerations of Neurocognitive Research on Outcomes of Cochlear Implantation in a Pediatric Population

What do the presented facts mean in the everyday life of pediatric CI users and their families who rely on spoken language for communication? There is abundant evidence that these children, regardless of the excellent pre- and post-operative conditions and the modern sophisticated technical solutions they use, achieve significantly poorer results on standardized language measures compared to their hearing peers [62]. Therefore, in this population, one can talk about general low-quality language stimulation (even language deprivation [20]), which is reflected in more developmental areas, such as perception, language, and speech, and consequently cognition, intelligence, and emotional, social, and academic success [63-65]. The consequences of "low-calorie" language stimulation in this population include poorly developed vocabulary [66,67], receptive and expressive morpho-syntactic skills [68-70], phonological awareness [71-73], and reading and writing skills [74,75]. As the expected increase in the complexity of language fails to emerge with increasing age, and as academic requirements start to become more demanding and difficult to fulfill, language delays become more obvious [76-78].

The aforementioned underdeveloped receptive and expressive language and speech skills of DHH children can be further connected to cognitive and socio-emotional domains, such as increased risk of emotional and behavioral difficulties and undesirable and destructive behaviors [79-81], generally weak social functioning [82,83], and increased risk of stigma, discrimination, and the appearance of mental problems such as depression [84,85]. People with hearing loss who have not developed the expected language competence (despite the advanced technological solution they use) in general have poor access to social services [86] and are at increased risk of emotional and physical neglect and abuse, sexual trauma, depression, and anxiety [87].

It should be noted that the increased developmental risks of inappropriate language stimulation presented in this way refer to children with hearing loss as a population [20]. CIs provide the best audibility compared to the preoperative pure tone thresholds at speech frequencies [88], and can enable competent spoken language use [20]. Therefore, the increased developmental risks should not be directly and exclusively linked to the technology of CIs but rather broadly viewed through all the factors considered responsible for the variable language outcomes in this population [60,61]. It is known that the development of the spoken language of children with CIs often does not correspond to expectations [23,89-91], but it should also be taken into account that under certain conditions (for example, with very early implantation and the best post-operative hearing results), the situation can be reversed [92,93]. Part of the variance in spoken language outcomes is related to habilitation variables, so successes in spoken language can be partially attributed to the appropriate adaptations of habilitation, based on constant monitoring of language progress and the factors that led to it [23]. The adaptation of the habilitation should be based on neurocognitive and other knowledge about the predictors of the success of language development after cochlear implantation, which certainly includes [52]:

1) Its earliest onset—before the end of the first year of life [94].

2) A further technological leap in the fidelity of the signal sent from the processor of the device to the brain, advances in programming strategies, and the promotion of language learning strategies based on recent research into working memory, cognitive development, and the preferred way of learning of DHH children [95,96].

3) Stronger involvement of families in habilitation, especially mothers, and their better empowerment to encourage early language development through continuous guidance and coaching, which is closely related to the overall success of the intervention [93].

## Communication Competence and Synergy of Sign Language and Cochlear Implantation Interventions

While waiting for technological advances in CIs, taking stronger measures in the earliest stages of habilitation to enrich the linguistic stimulation to which their pediatric users are exposed is of the greatest importance. Rich language stimulation includes [20]:

1) Educated and engaged family as the most important encourager of habilitation success, prepared to use daily situations for the development of communication, language, and speech by adding meaning to sounds (and not only speech sounds, but all sounds), to generalize them in everyday life, and to provide a socio-emotional context for communication and language experiences.

2) An expert team that will propose combinations of instructional and random learning strategies, detect the child's current abilities, determine the optimal learning content (compatible with the curriculum) and the difficulty of the tasks in the listening lessons, and determine the factors that promote or inhibit progress through continuous formal assessment.

3) Focus on communication competence or independent, sovereign, and purposeful communication, corresponding to age and cognitive abilities.

Therefore, rich language stimulation includes all communication resources, from auditory to visual communication solutions, meaning that in habilitation it is important to be aware of every sensory channel and their combinations that can shape the child's communication competence in the best possible way. Nevertheless, there are functional and qualitative differences between the use of various sensory channels to acquire more complete information (i.e., multimodal learning) and the use of the most elaborate communication systems for the same purpose (i.e., bimodal bilingual learning) [97-99]. Unfortunately, although contemporary literature highlights this scientifically based fact, surprisingly, few families have been encouraged to explore it [100]. However, evidence clearly indicates that ignoring the achievement of communication competence in DHH children, including children with CIs, and insisting on the development of spoken language carries a high risk of failing to acquire any language (language deprivation), which negatively affects cognitive development, academic success, socio-emotional health, and overall quality of life (for details see [20,101,102]). Today, we know that a precondition for neurocognitive development, and everything else that follows it developmentally, is language, but not necessarily spoken. It should be clearly stated that all developmental risks brought about by an incomplete approach to speech sounds and thus to spoken language can be avoided by encouraging the learning of sign language as an elaborate language system, in all its features parallel to spoken language. This should be done from the earliest age to take advantage of the critical language learning period, regardless of the use of CIs. DHH children who were exposed to sign language in a natural way (within the family) from the beginning are not at risk of developmental delays associated with children who were implanted but who did not acquire sign language [102-104]. The emphasis must be on early learning, since later learning of sign language, when it is clear that poorly developed spoken language skills do not allow effective communication (when sign language becomes "plan B"), does not allow the achievement of the highest levels of fluency [105]. Children with CIs who learned sign language from an early age achieve significantly better language and speech results than children who relied only on listening to speech in language learning [106,107], and have higher chances of achieving other developmental milestones [20,101,102], such as the development of self-esteem and good social skills [108]. Data on the quality of life of children with CIs and spoken language alone showed a positive impact of implantation on their communication, social relationships, self-reliance, confidence, and family well-being. Nevertheless, this positive impact is constrained, as the success of future education, further use of spoken language, and further support for a child remain parental concerns [109-111], indicating that the exclusive use of spoken language after cochlear implantation may still not be enough to meet developmental potential and parental expectations. Moreover, the general quality of life of children with CIs and their parents seems to be significantly lower than that of hearing children and their parents, as well as the care burden on parents of children with CIs, indicating that cochlear implantation does not necessarily eliminate psychosocial problems faced by these families [112]. One can argue that this is because language skill development after cochlear implantation only generally follows the trajectory of language development of typically developing children, with great individual variability relating to specific skills [113].

## Conclusion

Families of DHH children should be informed about the realistic reach of CI technology and about documented facts that bilingualism (the earliest exposure to natural sign language as a first language and parallel exposure to spoken language) prevents language and all other developmental delays, especially low literacy, which represents a permanent barrier to achieving a high quality of life [64]. The United Nations Convention on the Rights of Persons with Disabilities [114] ensures families of DHH children the right to bilingualism and highlights the benefits of achieving communication competence, that is, enabling upbringing and education in a language that children can access unhindered and in an environment that allows for the maximum development of all their potential (physical, cognitive, socio-emotional, and educational). Moreover, the Convention calls on policymakers to promote sign language, as it is an integral part of the right to free expression, seeking and receiving information, and organizing appropriate early intervention designed to prevent the development of further difficulties and disorders. Therefore, the implementers of early intervention must, immediately after identifying a DHH child, inform the family objectively and impartially about all habilitation options, which especially excludes the spread of linguistic prejudices and misinformation that sign language will hinder the development of speech [20]. Scientific evidence that early learning of natural sign language improves the outcomes of educational activities that precede or follow cochlear implantation is abundant. Therefore, it can be safely said that bilingual habilitation provides optimal conditions for the development of DHH children. The advantages of bilingualism are numerous [101]: it increases executive function (the brain is faster and has a stronger focus), enhances cognitive function and flexibility, improves language processing, and enables proper language and cognitive functioning. It is likely that parents, to whom the real achievements of CIs are explained, will finally be able to shift the focus of care from the imperative of speech development to the overall quality of life of their children, that is, towards building a healthy, respectful mutual relationship through which their children can develop into happy and self-confident individuals with full educational potential, capable of productive independent living.

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### Conflicts of Interest

The authors have no financial conflicts of interest.

### Author Contributions

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