EVALUATING THE RELATIONSHIP BETWEEN SPEECH PERCEPTION TESTS AND FUNCTIONAL OUTCOME MEASURES IN PEDIATRIC COCHLEAR IMPLANT RECIPIENTS

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CERTIFICATE

This is to certify that this dissertation entitled **"Evaluating the relationship between speech perception tests and functional outcome measures in pediatric cochlear implant recipients"** is a bonafide work submitted as part of fulfilment of the degree of Master of Science **Audiology** of the student with Registration Number **P01II24S023040**. This has been carried out under the guidance of a faculty of this institute and has not been submitted earlier to any other university for the award of any other Diploma or Degree.

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DECLARATION

This is to certify that this dissertation entitled **"Evaluating the relationship between speech perception tests and functional outcome measures in pediatric cochlear implant recipients"** is the result of my own study under the guidance of Dr. Jawahar Antony P., Assistant Professor of Audiology, All India Institute of Speech and Hearing, Mysuru and has not been submitted earlier to any other university for the award of any other Diploma or Degree.

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ABSTRACT

Speech perception testing in cochlear implant users give information on child’s listening abilities, however listening in everyday environment occurs in variable conditions and speech perception testing alone cannot account for real life listening situation and communication abilities of children with cochlear implant. The current study examined speech perception performance of two different speech perception tests and their association with functional hearing measures in children with cochlear implants. A within subject design was employed. Twenty two children with unilateral cochlear implants who fulfilled the inclusion criteria were involved in the study. Speech perception was measured through open-set word recognition test (OWT) and the Lexical Neighborhood Test (LNT) involving Easy and Hard word lists. On the other hand, the Functional Listening Index–Pediatric (FLI-P) was used to measure children's functional listening ability Results indicated that children's performance on the LNT was better compared to open-set word recognition test, showing higher scores on the LNT than word recognition task. Pearson’s correlation coefficient demonstrated that there was higher correlation co-efficient between OWT scores and FLI-P compared to LNT. The LNT Easy and LNT Hard scores were moderate to strongly correlate with FLI-P. These results suggest that though all speech perception tests were correlated with functional listening measure but in varying degrees. The strongest correlation was observed between OWT and FLI-P which indicates OWT assess the functional listening of children with cochlear implant. Thus, appropriate tests need to be selected to capture the real-life functional listening outcomes in pediatric cochlear implant users.

Keywords: cochlear implants, OWT, LNT, LNT easy, LNT hard, FLI-P, functional outcomes.

CHAPTER 1

Introduction

Speech and language development are closely tied to a child's ability to perceive and process auditory information (Kuhl, 2004). In children with hearing impairment, particularly those using cochlear implants (CIs), the development of spoken language relies on early and consistent access to auditory input, combined with appropriate auditory-verbal therapy and rehabilitation (Dornan et al., 2007). Evaluating how well these children perceive speech, especially at the word level, is critical in monitoring their language development and making better clinical decisions (Kirk et al., 1995).

The clinical utility of speech audiometry has been recognised for its diagnostic and prognostic value since the early 1950s (Hirsh et al, 1952). it has a distinct advantage over pure tone audiometry because speech is the most fundamental acoustic cue in human communication, making it a valid and sensitive tool for assessing the auditory pathway (Hirsh et al., 1952)

Speech based assessments reveal perceptual deficits that pure tone audiometry could not, particularly for pathologies affecting the retro cochlear regions and higher auditory pathways, which can be undetected even when subjective difficulties are present (Jerger & Hayes, 1971; Jerger & Jerger, 1974). The diagnostic value of speech based assessments has led to its widespread application in higher auditory structures (Kasden & Robinson, 1970). Numerous speech identification tests have been developed for children (Ross & Lerman , 1970; Elliot & Katz, 1980; Moog & Geers, 1990; Jijo & Yathiraj, 2008). But there is significant assessment gap which remains for specific paediatric population. Currently existing measures are often inadequate for children with cochlear implant, as they often fail to account for the variability in OWT (Cullington, 2000). This performance variability is influenced by factors such as age of onset, duration of hearing loss (Staller et al., 1991).

The variability in speech recognition among children with cochlear implants is further influenced by the duration of their device use, with performance often improving over time (Gantz, 1992). This developmental trajectory indicates the clinical need for a hierarchy of speech perception tests that progressively increase perceptual difficulty. Such a battery of assessments would allow clinicians to track auditory skill development more accurately as a child matures and gains more experience with their implant (Ching, 2013). A wide range of speech perception measures has been developed to meet this need, spanning from simple closed-set tasks such as the Word Intelligibility by Picture Identification test (Ross & Lerman, 1979) to more challenging open-set tests such as the Phonetically Balanced-Kindergarten (PB-K) word lists (Haskins, 1949).

The open-set speech perception test is one in which no choices are provided for the subject to make, unlike the closed-set speech perception test, where the subject is presented with words to listen to and repeat (Kirk et al., 1995). The chosen words of the open-set speech perception test are usually simple, with one or two syllables. They are also phonetically balanced and frequently used in everyday language. For children, the words are specifically drawn from their known vocabulary (Kirk et al., 1995).

The use of open-set speech perception tests to assess speech perception in cochlear implant users is valid, as closed-set tests are useful for children with very limited hearing and language skills but do not reflect real-world communication, which is open-ended (Clopper et al., 2006). Open-set tests are more challenging and provide a better measure of a child's ability to understand spoken language in everyday situations (Ching et al., 2013). As children with CIs gain experience and their auditory skills improve, they often outgrow closed-set tests. Open-set tests allow clinicians to track a child's on going speech perception progress over time and to demonstrate the benefit of the implant (Gantz, 1992).

Research has shown consistent improvements on these tests, directly linked to improvements in language, literacy, and academic performance in children with CIs (Geers, 2006). A child’s performance on OWT is a indicator of progress in spoken language. These test scores are frequently used to predict long term speech and language outcomes for children with cochlear implant (Moog & Geers, 1990; Mukari et al., 2007). However the research has shown that these OWT may not be suitable for all children, specifically for children with CI have been found to perform poor on PB-K test, the difficulty in the test possess the limited vocabulary (Mukari et al., 2007).

To address these challenges, the Lexical Neighbourhood Test (LNT) was developed to provide a more detailed evaluation of the perceptual processes underlying spoken word recognition, especially for children using cochlear implants (Kirk et al., 1995). The LNT is structured around two key Principles: word frequency (how common a word is) and lexical density. Lexical density refers to the number of phonetically similar words, or neighbours, surrounding a target word. Words with similar phonetic competitors stay in a dense lexical neighbourhood and those with few are in sparse neighbourhood. Based on the principles of word frequency and lexical density, the LNT words are categorised as either easy or hard words. A lexically ‘easy’ occurs frequently in the language and has a sparse neighbourhood, in contrast lexically ‘hard’ words occur less frequently and resides in a dense neighbourhood, surrounded by many phonetically similar words. This distinction is crucial for understanding a child's word recognition abilities (Kirk et al., 1995).

LNT is regarded for its utility in measuring word recognition in children with multichannel CI, providing reliable estimates across diverse speech perception abilities (Kirk et al., 1995). The primary strength of it lies in its ability to assess the perceptual process involved in speech perception.

The effective and robust design of LNT has led to its adaptation in various languages. International version includes Mandarin, Cantonese and Chinese. Recognising the linguistic diversity in India, the test has also been adapted to use with children who speak Indian English and Hindi, highlighting its cross linguistic value (Singh, 2010; Yang & Wu, 2005; Yuen et al., 2008; Liu et al., 2011; Patro & Yathiraj, 2010).In the context of Kannada-speaking children, the LNT has been adapted and standardised using materials developed by Apoorva and Yathiraj (2013) to ensure cultural and linguistic relevance. This Kannada version of LNT includes carefully selected multisyllabic, phonetically balanced, and age-appropriate words, categorised by lexical frequency and neighbourhood density.

In order to evaluate a cochlear implant's effectiveness, it is important to use functional outcome measures, such as speech perception, to assess treatment outcomes. Unlike clinical tests, which are limited to controlled environments, the functional measures assess patients' real-world abilities. Neuman et al. (2010) reported that assessing speech perception in noisy environments is essential for understanding children's real-life listening performance, as they spend a significant part of their daily activities in such conditions. Correlating speech perception performance with functional outcome measures would help understand children's overall auditory capacity (Tyler et al., 1997).

Several studies have evaluated the relationship between speech perception scores and functional outcome measures in children with cochlear implant and reported that speech perception are limked strongly to functional outcomes with early proficiency and broader language success (Geers et al., 2011; Nada et al., 2024; Sreekumar et al., 2024). It is suggested that speech perception performance often correlates with broader communication outcomes such as language development, academic performance, and social interaction (Geers, 2006). Pisoni et al. (1997) reported strong correlations between LNT performance and other measures of spoken language processing in paediatric cochlear implant users. Their findings indicated that children with higher LNT scores also demonstrated better performance on sentence recognition tasks and speech intelligibility measures.

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Studies have shown that speech perception test alone would fail to reflect the real-life listening situations of the hearing-impaired in Indian context (Kumar & Kameswaran, 2018, Jain et al., 2018; Bhat et al., 2024). However, correlation with the Indian speech perception test performance and the real world functional auditory abilities in children with hearing impairment has not been widely studied. There is a dearth of literature to establish the relation between the performance in Indian language speech perception test and real-world communication outcomes.

Justification for the Study

Evaluation of the relationship between speech perception tests and functional outcomes in children with cochlear implants (CI) is critical in gaining an overview of the patient's improvement (Tyler et al., 1997). The primary aim in comparing speech perception tests and functional outcomes is to determine whether it measure the actual ability of the child in communicating through speech (Tyler et al., 1997). An association between speech perception scores and functional outcomes indicates the effectiveness of speech perception tests in predicting future speech and language development (Moog & Geers, 1990). Through this relationship, clinician will be able to learn about the strengths and weaknesses of the child in order to improve their rehabilitative interventions (Ching et al., 2013). Assessment of functional outcomes together with the test scores will provide evidence on how child responds to real world communication.

Existing word identification tests for children with hearing impairment has two. One end are simple tasks, such as pattern perception, while on the other are challenging open-set word tests that may become more complex in the presence of background noise. A test that is too simple cannot capture small perceptual difficulties, while one that is too difficult may provide an inaccurate picture of their abilities. This creates the need for a test that strikes a balance between simplicity and complexity. The LNT addresses this gap, providing a balanced tool for monitoring a child's perceptual development (Kirk et al., 1995).

A key limitation of many speech tests developed for Indian children with hearing impairment is their dependence on a single factor that is word familiarity (Mayadevi, 1974; Prakash, 1999; Jijo & Yathiraj, 2008). However, factors such as word frequency and lexical density also influence a child's ability to perceive speech (Kirk et al., 1995; Dirks et al., 2001). Studies have reported that children with cochlear implants often perform poorly on open-set speech perception tests such as the PB-K because these lists contain words unfamiliar to young deaf children, who typically have a limited vocabulary (Mukari et al., 2007). In this context, the LNT is particularly useful because it incorporates lexical factors, offering clearer insights into auditory skills. This makes it valuable for identifying even small perceptual challenges in children using cochlear implants and for evaluating them before advanced tests, such as PB word lists. Additionally, it provides clinicians with a means to assess device effectiveness and track progress over time.

However, it has yet to be established which Kannada speech perception test score reflects cochlear implant user's performance in everyday listening situations better. Correlating these scores with subjective measures of functional outcomes is therefore essential (Ross & Lerman, 1970). Understanding how well Indian-language speech tests capture functional outcomes in paediatric CI users is important, as it will guide the selection of appropriate measures for both clinical and research purposes. Thus, the ability to evaluate outcomes in paediatric cochlear implant recipients and ensure that the chosen speech perception tests accurately depict their real-world communication abilities.

Aim of the study

The study aims to evaluate the relationship between different speech perception tests and functional outcome measures in paediatric cochlear implant users.

Objectives of the Study

1) To compare the speech perception performance between the LNT and the open set word identification test (OWT) in children using cochlear implants.
2) To investigate the association between the functional listening outcome measure and the performance of the LNT and the OWT in children using a cochlear implant.

The Hypotheses of the Study

The null hypotheses for the objectives are given below;

Objective 1(H_0): There is no significant difference between speech perception performance between the OWT and LNT.

Objective 2(H_0): There is no correlation between speech perception tests and functional listening outcome measures.

CHAPTER 2

REVIEW OF LITERATURE

2.1 Speech Perception and Auditory Development in Children with Hearing Impairment

Speech perception plays a fundamental role in the development of spoken language in children. The ability to perceive and process auditory information enables children to acquire phonological representations, vocabulary, and grammatical structures necessary for effective communication. Research has shown that early auditory experiences are critical for language development, as the auditory system undergoes rapid neural maturation during early childhood (Kuhl, 2004). When children are deprived of adequate auditory input during developmental period the speech and language acquisition may be delayed..

For children with hearing impairment CI is one of the most effective interventions for restoring auditory input. Cochlear implants provide electrical stimulation to the auditory nerve, in turn allowing children to perceive speech signals (Dornan et al., 2007).Speech audiometry has been recognised as an essential component in evaluation of auditory system. Hirsh et al. (1952) reported that speech based assessments provide diagnostic and prognostic information about auditory performance. It provides information on how acustically complex signals reflect everyday communication (Jerger 7 Hayes, 1971).

Jerger & Jerger (1974) highlighted the clinical significance of speech audiometry by demonstrating that certain auditory pathologies, particularly those involving retro cochlear structures may not be detected by pure tone audiometry alone, speech perception testing therefore play an important role in evaluating the functional integrity of auditory system.

2.2 Importance of Speech Perception in Paediatric Recipients

Speech perception evaluation is a fundamental clinical aspect for determining the success of cochlear implantation in children with hearing impairment. Standardised evaluations allow for measuring a child's ability to detect, discriminate, and identify the acoustic cues of spoken language (Robbins & Iler Kirk, 1996). These evaluations provide the essential data required for the longitudinal monitoring of auditory development and are critical for validating the effectiveness of the implant (Robbins & Kirk, 1996).

The ability to perceive speech is a key indicator of language development and the successful physiological integration of the cochlear implant (Elsayed, 2022). High speech perception scores suggest that the child is successfully building a mental representation of phonemes, which facilitates the growth of a mental lexicon (Kuhl, 2004). These hierarchical levels of perception are essentially the building blocks required for the transition to complex open-set word recognition in regional languages (Apoorva, 2012).

The clinical significance of these tests is further highlighted by their role in refining and evaluating the impact of early intervention. Recent research suggests that the duration of hearing aid use and specific threshold levels should be considered before proceeding to bilateral implantation (Davidson et al., 2019). Studies have reported that children with higher speech perception sores in their post implant period achieve better outcome (Hunter et al., 2017). Therefore speech perception testing is an important aspect which links to real world listening situations (Robbins & Kirk, 1996).

To assess the benefit of cochlear implantation in children various perceptual evaluations have been developed. Closed set measures, which require the child to slect the target word heard from a set of pictures presented. Findings indicate that approximately half of the CI population achieve good scores in closed set measure which may lead to ceiling effect of 80 to 100% (Tyler, 1993). However it has been noted that high performance in children may still reflect underlying perceptual difficulties which can be revealed by tests like OWT (Tyler, 1993).

OWT is considered as the gold standard for measuring child's ability to recognise words mainly through auditory mode by removing pictures. Unlike closed set tasks in which child chooses from a limited set of options, OWT requires the child to identify words mainly through auditory mode (Robbins & Kirk, 1996).The clinical implication of OWT arises from its ability to assess the auditory system in ways that simpler tasks cannot. While a significant proportion of CI users achieve high scores on closed set tasks, these results often mask underlying difficulties in resolving speech in absence of limited response set (Dawson et al., 1992).

OWT enable child to retrieve labels from mental dictionary which provide more accurate reflection of true auditory behaviour (Geers et al., 2003).Open-set performance serves as a vital marker for monitoring developmental progress and the efficacy of early intervention. Research indicates that the emergence of open-set recognition is a significant milestone that often correlates with later improvements in academic performance, such as reading proficiency (Spencer & Oleson, 2008). Monitoring these skills over time allows the clinical team to verify that the child is benefiting from early access to sound and that the implant is providing a sufficiently detailed signal for language acquisition (Dawson et al., 1992; Geers et al., 2003). If a child fails to progress toward open-set after several years of use, it provides an objective basis for re-evaluating device mapping or therapeutic strategies (O’Donoghue et al., 1998).

The variables influencing successful open set outcomes are diverse, but age at implantation remains a consistent factor across the provided literature. Children implanted at younger age those under 5 years of age are more likely to achieve OWT scores within first few years of CI use (Waltzman et al., 1997). Longitudinal data suggest duration of implant use increases the percentage of OWT scores (O’Donoghue et al., 1998; Dawson et al., 1992) OWT scores are an important toll in making clinical and rehabilitative decisions. The ability to recognise speech without lip reading is the indicator of functional benefit of CI (O’Donoghue et al., 1998). These tests help clinician to determine the potential benefits of the implant in real world communication situations where visual cues may be absent. OWT provide the evidence based foundations required to tailor the rehabilitation of children with hearing impairment (Spencer & Olenson, 2008; Waltzman et al., 1997).

The Lexical Neighbourhood Test (LNT) is a open-set measure developed to assess speech recognition in children with limited vocabularies, based on the Neighbourhood Activation Model (NAM). The NAM shows that word recognition is a process of competitive activation, where a child must distinguish a target word from phonetically similar neighbours (Kirk et al., 1995). The LNT uses Lexically Easy words (high frequency, few neighbours) and Lexically Hard words (low frequency, many neighbours) to determine how effectively a child resolves this lexical competition (Kirk et al., 1995). By utilising words familiar to young children, the LNT ensures that scores reflect auditory recognition rather than a lack of vocabulary knowledge (Robbins & Kirk, 1996).

The clinical utility of LNT is in its ability to highlight small differences in auditory processing that traditional test would miss. Research on Kannada speaking population emphasises that the test structure is sensitive to linguistic characteristics of the child's native language (Apoorva & Yathiraj, 2012). This differentiation allows clinicians to point specific auditory discrimination deficits. Furthermore, the LNT is highly sensitive to stimulus levels, with scores often decreasing significantly when speech is presented at low levels (Davidson, 2019).

Research shows that the age of implantation and the duration of device use are the primary factors influencing success on the LNT. Early implantees—those receiving implantation before age three demonstrate significantly higher LNT scores than late implantees (Kant & Banik, 2017). This suggests that early access to sound allows the auditory brain to organise the mental lexicon more efficiently, reducing the cognitive load required for word recognition (Zhou et al., 2023). The LNT thus serves as a critical diagnostic tool for measuring the success of early intervention and the impact of the sensitive period for auditory learning (Hunter et al., 2017).

The LNT helps in evaluating the impact of pre-implant acoustic hearing on post-implant performance. Children who had consistent access to acoustic hearing through well-fitted hearing aids before their surgery tend to show faster progression on LNT tasks (Nickerson & Davidson, 2019). These findings show that the LNT captures a child's overall auditory performance, reflecting how effectively they have utilised auditory stimulation over time (Nickerson & Davidson, 2019). By controlling for vocabulary age, the LNT provides a pure measure of how well the auditory system processes and categorises complex speech signals (Robbins & Kirk, 1996).

LNT is increasingly used to compare outcomes across diverse patient populations, including those with auditory neuropathy spectrum disorder (ANSD) or inner ear malformations. Studies have utilised the LNT to show that children with ANSD may have varied outcomes, but those with better temporal processing often achieve significant open-set recognition (Mostafa et al., 2023). In cases of cochlear malformations, the LNT has revealed that while these children can achieve open-set speech recognition, their plateau is often lower than that of children with normal anatomy (Bakr et al., 2024). Thus, the LNT remains a versatile and essential tool in the Audiological test battery, providing insight into the potential of paediatric cochlear implantation (Kant & Banik, 2017).

2.3 Indian Speech Perception Test in Children

Speech perception testing acts as important aspect of speech and language development in children with hearing impaired. In typically developing children the ability to detect, discriminate, identify and comprehend speech sounds follows a relatively predictable developmental trajectory that is directly linked to auditory input (Geers et al., 2018). Nandurkar (2019) pointed out that clinical assessment of speech perception skills in young children is critical but yet underserved, primarily due to lack of age-appropriate speech perception tests in Indian languages.

Indian adaptations have been developed across several languages. Bhimte and Rangasayee (2018) developed the Hindi Early Speech Perception Test using phonologically appropriate Hindi stimulus drawn from the vocabulary of Hindi speaking children. Priya (2017) developed the Modified ESP in Kannada (MESP-K) at AIISH, Mysuru. Jijo & Yathiraj (2010) developed Malayalam version, and Begum (2000) developed a version in

Indian English. Together these adaptation show that ESP framework has been accepted and widely applied across Indian languages

OWT is another set of speech perception tests that is more reflective of real life listening than closed set task. The OWT used in Indian languages acts as a key milestone in cochlear implant rehabilitation. Kant and Pathak (2015) noted that children with hearing impairment require at least 20% response on LNT before open set assessment of more complex speech skills. This means that OWT has a higher order structure which reflects real life listening demands.

Rajashekar (1976) developed and standardized a picture based speech recognition threshold test for Kannada speaking adults and children. Yathiraj & Vijayalakshmi (2010) later developed phonemically balanced word lists in Kannada specifically for children, with words familiar to children aged five and above. Arya & Aparna (2016) showed that Hindi speaking children on open set and minimal pair tasks. This advantage was strong on phonemically demanding items which reflect OWT as a clinical outcome measure in Indian context.

The LNT as an open set speech perception tool is based on NAM model (Kirk et al., 1995).the main idea is that words are not recognised in isolation but they compete with other phonologically similar words in the listener's mental lexicon. Applying this into Indian languages required building entirely new word lists. Kant & Banik (2017) collected natural language samples from 120 Hindi speaking children aged three to five years at AYJNISHD Mumbai, and computed frequency and neighbourhood density for each word and built mono and multisyllabic easy and hard word lists. These were tested on 45 cochlear implant users one year post implantation, the children showed clear lexical difficulty effects depicting higher scores on LNT easy than on hard words, which confirms lists were valid and that LNT framework generalizes to Hindi.

Kant & Pathak (2015) used the LNT and MLNT with early and late implanted Indian children and analysed phonological errors made by children. Late implantees scored relatively better on the LNT and MLNT, suggesting they were using word length as a perceptual cue to compensate for weaker phoneme level processing. Early implantees made deletion errors while late implantees made substitution errors. This point to qualitative difference at different stages of auditory development and its direct implications for planning AVT. These findings collectively establish the LNT framework as a clinically valuable tool in the Indian cochlear implant recipients.

2.4 Importance of Functional Outcome Measures

Functional outcome measures are essential as they measure the real world application of child's listening skills, moving beyond the assessments seen by speech perception tesing. Functional outcome measures evaluates effectiveness in naturalistic environment where noise, visual distractors are present (Davis et al., 2022). These measures often based on parent reports which provide a overall view of child's participation in social and educational setting (Bark et al., 2024). Without functional data clinician may overestimate the child's performance. The significance of functional outcomes is evident in children from diverse linguistic background, where standardised tests may be culturally or cognitively biased. Functional outcome measures allow flexible assessment of progress which focuses on how a child uses their hearing to interact with family and peers and they also provide active parent involvement (Yu et al., 2024). By identifying discrepancies in children functional measures enable the implementation of more targeted and personalised rehabilitation statergies (& Van

Zalk., 2025).Functional outcome measures are also critical for justifying the long-term benefits of cochlear implantation. Showing that a child has reached age-appropriate functional milestones provides evidence of the implant's value to parents (Cowan et al., 2024). Furthermore, these measures are sensitive to factors that booth-based tests cannot capture, such as the impact of consistent daily device use and the quality of the home linguistic environment (Bakr et al., 2024). Ultimately, functional assessments ensure that the primary goal of implantation improving the child's quality of life and social participation—is being met (Davis et al., 2022).

2.5 Use and Utility of the Functional Listening Index-Paediatric (FLI-P)

The FLI-P is a 64 items checklist which is designed to track the acquisition of listening skills in infants and young children’s with hearing loss. It has 6 phases in progressive form starting from sound awareness to comprehension of complex language in social and academic setting (Davis et al., 2022). The FLI-P is unique because it provides normative data allowing clinician to plot child’s listening trajectory based on their listening age (Davis et al., 2022).this outcome measure is important in order to identify children who are falling behind their expected developmental abilities (Cowan et al., 2024).FLI-P is important for evaluating the progress of children with HI. The FLI-P enables more precise measurement of their functional gains (Cowan et al., 2024). The FLI-P is structured in such a way to understand the developmental trajectory (Davis et al., 2022).The FLI-P is used in research to validate new intervention strategies and technology. By comparing listening trajectories across different groups of children, researchers can determine which factors lead to the most robust functional outcomes (Corbett & Van Zalk, 2025). This data is important for evolving the standards of care in paediatric audiology (Davis et al., 2022). In summary, the FLI-P is a foundational tool that brings clinical precision to the assessment of functional listening in everyday life (Cowan et al., 2024).

The relationship between speech perception tests and functional measures helps evaluate real-life performance. A child's ability to achieve high scores on open-set tests such as LNT indicates that they possess the phonetic discrimination and lexical access necessary for real-world listening (Robbins & Kirk, 1996). Research has shown a strong positive correlation between these two domains; as a child's open-set recognition improves their ability to process complex social and linguistic items on the FLI-P (Davis et al., 2022). This correlation suggests that clinical perception scores provide the foundational blocks for functional communication (Cowan et al., 2024).

However, a high clinical score does not reflect high functional performance, highlighting the significant influence of real-life situations. A child may perform well in a quiet environment but struggle in a classroom setting due to executive functioning challenges or environmental noise (Hunter et al., 2017). Some children with moderate clinical scores demonstrate high functional competence through effective use of context and visual cues (Bakr et al., 2024). This divergence between clinical and functional measures is a critical diagnostic indicator, suggesting that a child may require support beyond simple device adjustments (Davis et al., 2022).

Evaluating the relationship between speech perception tests and functional outcome is essential measure in understanding the child’s real life listening abilities. Speech perception measures like LNT provides measure of child’s ability to resolve lexical competition (Robbins & Kirk, 1996), the FLI-P tracks the practical application of these skills across developmental stages (Cowan et al., 2024). By integrating both the types of measures it helps to know the actual listening development of children in real world communication situations (Bark et al., 2024).

CHAPTER 3

METHOD

3.1 Research Design

The present study evaluates the relationship between speech perception tests and functional outcome measure in paediatric cochlear implant recipients, using a within subject design.**3.2**

3.2 Participants

The present study included 22 children with unilateral cochlear implants. Participants were selected through purposive sampling, and all fulfilled the specified audiological and speech-language inclusion criteria. Ethical approval for the study was obtained from the Institutional Review Board, and informed written consent was obtained from the children's guardians prior to participation. The study group comprised 11 male and 11 female participants aged between 5 to 8 years. The demographic details of the participants are given in Table 1. All children were native Kannada speakers belonging to Kannada-speaking families and had received auditory-verbal therapy in Kannada following cochlear implantation. All participants were users of a unilateral cochlear implant system manufactured by Cochlear Limited, specifically the CI 422 implant coupled with the Nucleus 7S (CP1002) speech processor. To be eligible for inclusion, children had to be younger than 8 years of age and demonstrate receptive and expressive language skills equivalent to a developmental age of at least 36 months, as assessed using the Assessment Checklist for Speech and Language Skills (ACSLS) (Swapna et al., 2006). Furthermore, participants were required to have attained and maintained a minimum closed-set speech perception score of 80% for at least 1 year after implantation and to have used their cochlear implant consistently for at least 1 year before participation in the study. In addition, all children had undergone regular auditory-verbal rehabilitation sessions for at least 12 months following implantation. Children with associated neurological, cognitive, developmental, or additional sensory impairments were excluded from the study. Participants presenting with cochlear implant electrode abnormalities, including open or short circuits or electrodes deactivated because of non-auditory sensations, were also excluded. Moreover, children with inconsistent cochlear implant use, irregular participation in rehabilitation programmes, insufficient post-implantation auditory rehabilitation, or device-related complications were not included in the study.

Table 1

Demographic details of participants in the study (N = 22)

Characteristic	M	SD
Participant age (years)	6.28	0.65
Age at cochlear implantation (years)	4.45	0.61
Duration of cochlear implant use and rehabilitation therapy (years)	1.83	0.43
Aided PTA average (500Hz, 1kHz, 2 kHz, 4 kHz) in dBHL (with loudspeaker at 1m distance).	20.5	2.75

Note. M = mean; SD = standard deviation; PTA = Pure Tone Average.

3.3 Instrumentation

A calibrated two-channel diagnostic audiometer (Inventis Piano) and sound-field speakers were used to estimate speech identification performance, which was connected via a 3.5mm stereo AUX cable to an HP computer running Windows 11 and a 64-bit operating system, which presented the stimuli for the speech perception tests. Along with this, a smartphone was used to record the child's responses, which was kept close to them.

3.4 Test environment

Testing was done in a sound-treated room with noise levels within the permitted limits per ANSI/ASA S3.1-1999 (R2018). The lighting and temperature of the test room were adequate and comfortable enough for the subject. Participants were seated comfortably at 1 meter from the loudspeaker, which was positioned at 45° azimuth, and the loudspeaker was switched on to the side of the implant accordingly.

3.5 Test Material

Speech perception performance was assessed using a recorded version of Open-set word identification test (OWT) material for children in Kannada (Saransh et al., 2015) and the Lexical Neighbourhood Test in Kannada (LNT) (Apoorva & Yathiraj, 2012). To compare it with functional outcomes, functional listening abilities were assessed using the Functional Listening Index – Paediatric (FLI-P), which evaluates real-world auditory behaviour across everyday listening contexts (Davis et al., 2022).

3.6 Procedure

Initially, the OWT and LNT were loaded onto the computer. The computer's output was routed to the sound field speakers via a diagnostic audiometer. The loudspeaker was placed at 450 ° azimuth, 1 meter from the listener's head. Prior to stimulus presentation, the 1 kHz calibration tone was played to adjust the audiometer's VU meter to ‘0’. The stimuli were presented in a sound-field condition at 45 dB HL. The children were made to sit alone and comfortably in the sound-treated audiometric test room. If the child was uncomfortable, the child's parents were made to sit next to the child and instructed not to help the child during the test. The hearing aid in the contralateral ear was switched off if used. The child was instructed to repeat what they heard. To ensure they understood the instructions, they were first made to listen to orally presented practice items that were not part of the test items. Following this, recorded test items were presented. Two tests were carried out OWT and the LNT. The two tests were randomised within subjects to reduce order-list bias.

The OWT contains 25 words per list. Two lists were randomly selected for the study. Similarly, the LNT had 2 lists, each containing 13 lexically easy and 12 lexically hard words, for a total of 25 words per list. Here, the order of presentation was randomised between LNT and OWT and the list across participants to reduce the order and list effects. The participants' verbal outputs were video-recorded by the tester and transcribed in the International Phonetic Alphabet (IPA).

To minimise the influence of articulation-related distortions on speech perception scoring, speech production abilities were evaluated using the Kannada Diagnostic Photo Articulation Test (KDPAT) (Deepa & Savithri, 2010). Speech samples obtained during testing were transcribed using the (IPA), and articulation errors identified through KDPAT were analysed according to substitution, omission, distortion, and addition (SODA) patterns. Responses were scored after accounting for speech-production errors to ensure that incorrect articulatory output was not misinterpreted as reduced speech-perception ability. Then, from the video sample, the responses were analysed, and each correctly identified word was assigned a score of 1, whereas incorrect responses received a score of 0. The maximum obtainable score for both tests was 25.

To evaluate the functional outcome measures, the FLI-P (Functional Listening Index-Paediatric) was used. The FLI-P is a hierarchical 64-item checklist divided into 6 phases, which is designed to track the acquisition of listening skills in infants and young children with hearing loss. Phase 1 evaluates sound awareness (7 items), Phase 2 evaluates associating sound with meaning (11 items), Phase 3 evaluates comprehending Simple Spoken Language (12 items), Phase 4 evaluates comprehending language in different listening conditions (11 items), Phase 5 evaluates listening through discourse and narrative (14 items), and Phase 6 evaluates advanced open-Set Listening (9 items). Each item has a binary choice, and the parents must respond to these items based on the child's performance. The total FLI-P score represented the child’s overall functional auditory performance across naturalistic communication contexts (Davis et al., 2022).

The primary caregiver, identified as the most suitable respondent, was seated comfortably in a quiet room. The clinician explained that the focus is on the child’s typical auditory behaviour in daily life. Each item was scored as either ‘Rarely’ with a score value of 0 or ‘Mostly’ with a score value of 1. During the interview, each question was explained in their native language, supplemented with situational probes to elicit detailed responses. For example, when asked whether the child hears all the ling 6 sounds when presented with emphasis, caregivers were guided with behavioural scenarios and instructed on the scoring criteria, where ‘Rarely’ indicates the child hears ling six sounds not consistently and ‘Mostly’ indicates that the child listens to all the 6 sounds of ling most often. A similar pattern was followed across all 6 phases, which cover all 64 items. The maximum attainable score for the FLI-P was 64 and 'Mostly' response was recorded for each child to calculate the total scores. Further, these scores were used for statistical analysis.

3.7 Statistical Analysis

In line with the objectives of the study, data from each participant were tabulated and analysed using the Statistical Package for the Social Sciences (SPSS for Windows, Version 32). Initially, all variables were subjected to descriptive and inferential statistical analysis, including computation of the mean and standard deviation.

The Shapiro-Wilk test was used to assess the normality of the data distribution, and it showed that OWT, LNT, and FLIP scores were normally distributed, whereas LNT easy and LNT hard were nearly normally distributed. The values are presented in Table 2.

Table 2

Tests of Normality for OWT, LNT, and FLI-P Scores (N = 22)

Variable	***W***	***Df***	***p***	**Interpretation**
OWT	.927	22	.105	Normally distributed
LNT	.914	22	.056	Normally distributed
LNT Hard Score	.877	22	.011	Near normally distributed
LNT Easy Score	.829	22	.002	Near normally distributed
FLI-P Score	.930	22	.125	Normally distributed

Note. W = Shapiro–Wilk statistic was derived from descriptive statistics. Normal distribution seen for OWT and FLIP, and near-normally distributed for LNT Easy and Hard, given the sample size (N = 22) and minimal skew, parametric analyses were considered appropriate (Field, 2018).

To examine differences in speech perception scores between the OWT and the LNT, a paired *'t'* test was conducted. The relationship between speech perception scores and functional listening outcomes (FLI-P scores) was analysed using Pearson's product-moment correlation coefficient.

CHAPTER 4

RESULTS

This study aimed to evaluate the relationship between speech perception tests and functional outcome measures in paediatric cochlear implant users. The responses of 22 children with cochlear implants were analysed using appropriate statistical methods, and the test results are presented below.

This chapter is organised into the following sections

4.1 Comparisons of speech perception scores of OWT and LNT

4.2 Correlation of OWT with FLI-P

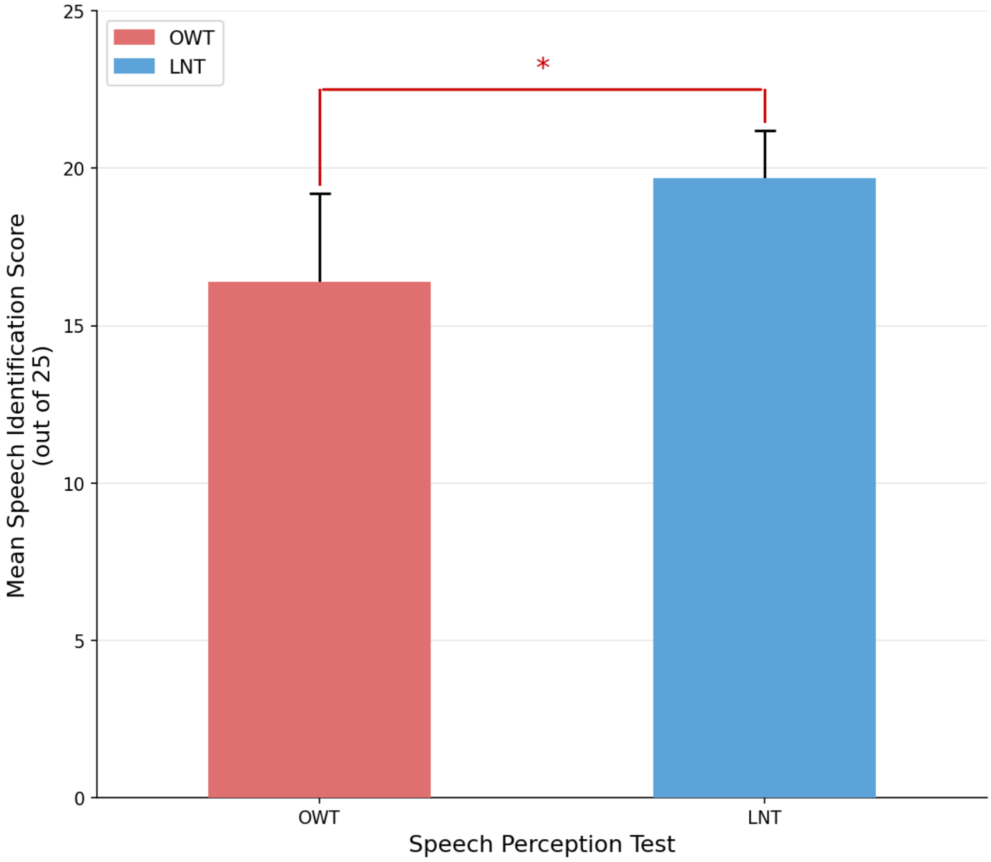
4.3 Correlation of LNT with FLI-P

4.4 Correlation of LNT easy and LNT hard with FLI-P

4.1 Comparison of Speech perception scores of OWT and LNT in paediatric cochlear implant recipients.

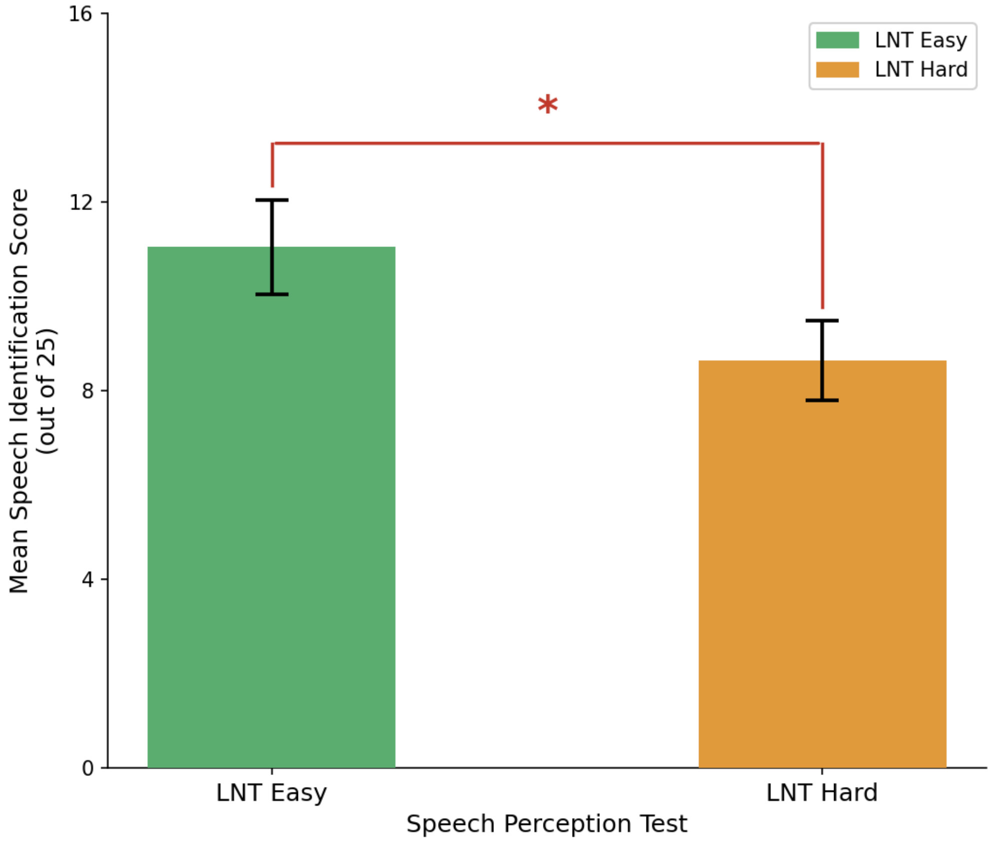
Descriptive statistics were done to calculate the mean and standard deviation. The mean scores indicated higher scores in speech perception in LNT. Descriptive statistics for all measures are presented in Table 2. The mean OWT was $M = 16.32$ ($SD = 2.53$) out of a maximum of 25, whereas the mean LNT total score was notably higher at $M = 19.68$ ($SD = 1.52$) out of 25. For the LNT subcomponents, mean scores were $M = 8.64$ ($SD = .85$) for LNT Hard and $M = 11.05$ ($SD = .999$) for LNT Easy. The mean FLI-P score was $M = 48.50$ ($SD = 4.39$).

Figure 1. *Speech Identification Scores for OWT and LNT Tests*



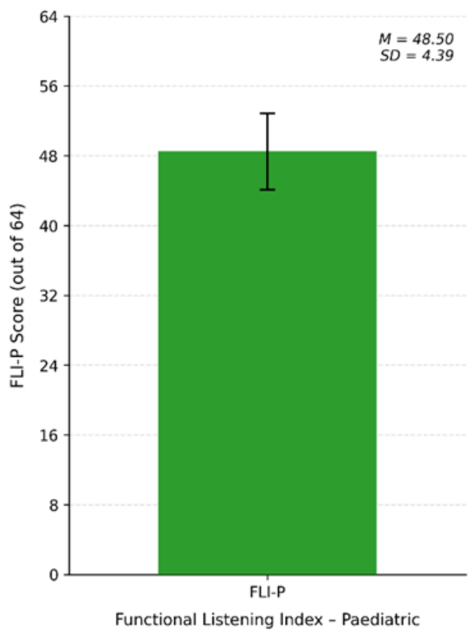
Note. Mean speech identification scores of OWT and LNT (out of 25; x-axis) with error bars represent ±1 standard deviation. Significance brackets indicate differences between the OWT and LNT (*p < .001).

Figure 2. *Speech Identification Scores for LNT easy vs LNT hard*



Note. Mean speech identification scores of LNT easy and LNT hard (out of 25; x-axis) with error bars representing ±1 standard deviation. Significance brackets indicate differences between the LNT easy and LNT hard (*p < .001).

Figure 3 *Mean FLI-P Score in Paediatric Cochlear Implant Users (N = 22)*



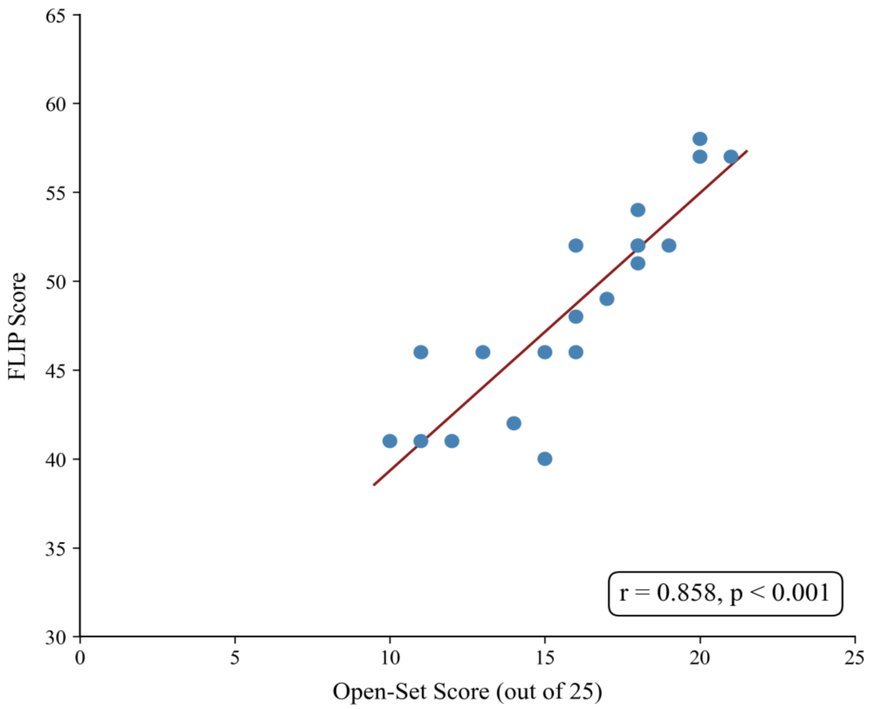
Note. FLI-P; Total score range = 0–64. Error bars represent standard deviation, N = 22. Mean = 48.50 (75.78% of maximum), SD = 4.39.

To test whether the difference in performance between the OWT and LNT was statistically significant, a paired-samples *t*-test was conducted. Results revealed a statistically significant difference between OWT and LNT scores [$t(21) = –10.319$, $p < .001$, $d=2.20$], indicating large effect size and improved speech recognition with LNT than with OWT (Cohen's, 1988)

4.2 Correlation of OWT and FLI-P.

To assess the correlation, Pearson's correlation was used to examine the relationship between FLI-P scores and OWT. A statistically significant, strong positive Pearson's product-moment correlation was found between OWT scores and FLI-P scores ($r = .821$, $p < .001$) (Dancey & Reidy, 2007). This indicates that children who scored higher on the OWT tended to receive higher FLI-P scores, reflecting stronger functional listening in daily environments. The scatter plot in Figure 4 illustrates this strong positive monotonic relationship, with data points clustering reasonably close to the regression line.

Figure 4. *Scatter Plot of Open-Set Word Identification Scores and FLI-P Scores.*

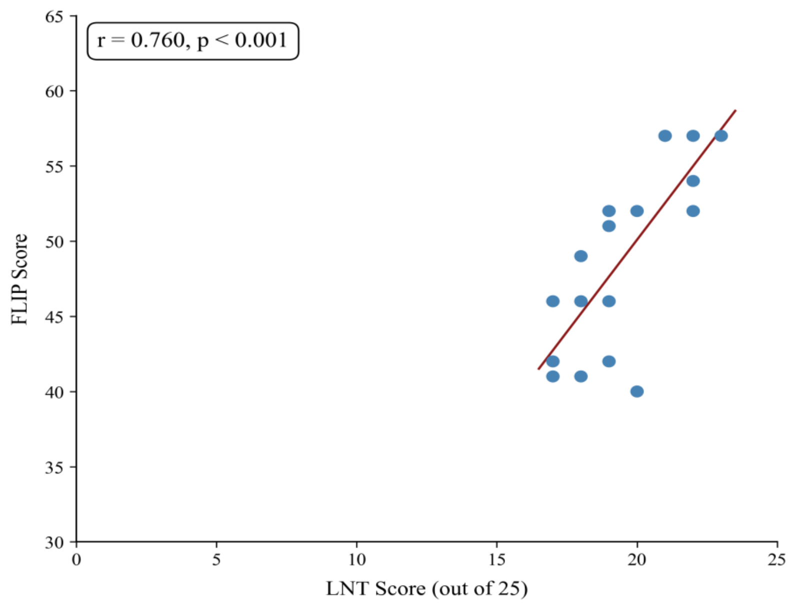


Note. Depiction of OWT scores (out of 25; x-axis) plotted against FLI-P total scores (out of 64; y-axis). Solid lines represent ordinary least squares regression lines. Pearson product-moment correlation coefficient (r) and two-tailed exact p-values are presented.

4.3 Correlation of LNT with FLIP

A Pearson product-moment correlation was conducted to examine the relationship between (LNT) scores and functional listening performance as measured by the (FLIP). Results revealed a statistically significant positive correlation between LNT scores and FLIP scores (r = .760, p < .001) (Dancey & Reidy, 2007). This indicates that children who obtained higher scores on the LNT demonstrate functional listening in real-life situations. However, the correlation co-efficient between OWT and FLIP is stronger than that between LNT and FLIP. The scatter plot in Figure 5 represents the scatter plot of LNT with FLIP.

Figure 5. *Scatter Plot of LNT total scores and FLI-P Scores*

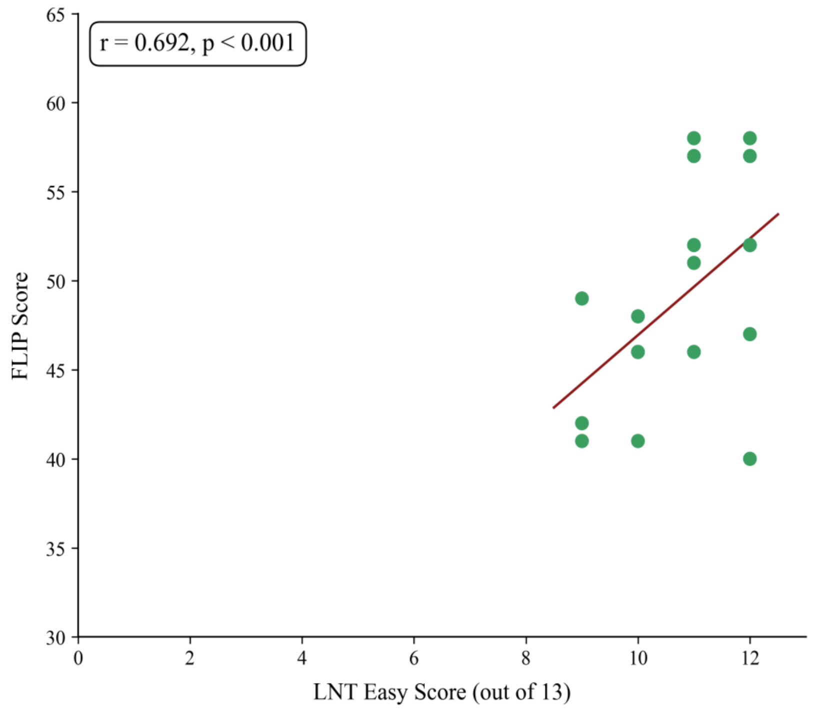


Note. Depiction of LNT (out of 25; x-axis) plotted against FLI-P total scores (out of 64; y-axis). Solid lines represent ordinary least squares regression lines. Pearson product-moment correlation coefficient (r) and two-tailed exact p-values are presented.

4.4a Correlation of LNT Easy and FLI-P.

For further analysis, a correlation analysis was conducted to examine the relationship between LNT Easy and FLI-P, and it showed a statistically significant, moderate-to-strong positive Pearson product-moment correlation ($r = .650$, $p < .001$) (Dancey & Reidy, 2007). Although correlation of OWT with FLI-P was stronger than LNT easy with FLI-P ($r = .821$) the scatter plot in Figure 6 displays moderate clustering around the regression trend line.

Figure 6. *Scatter Plot of LNT Easy Speech Identification Scores and FLI-P Scores.*

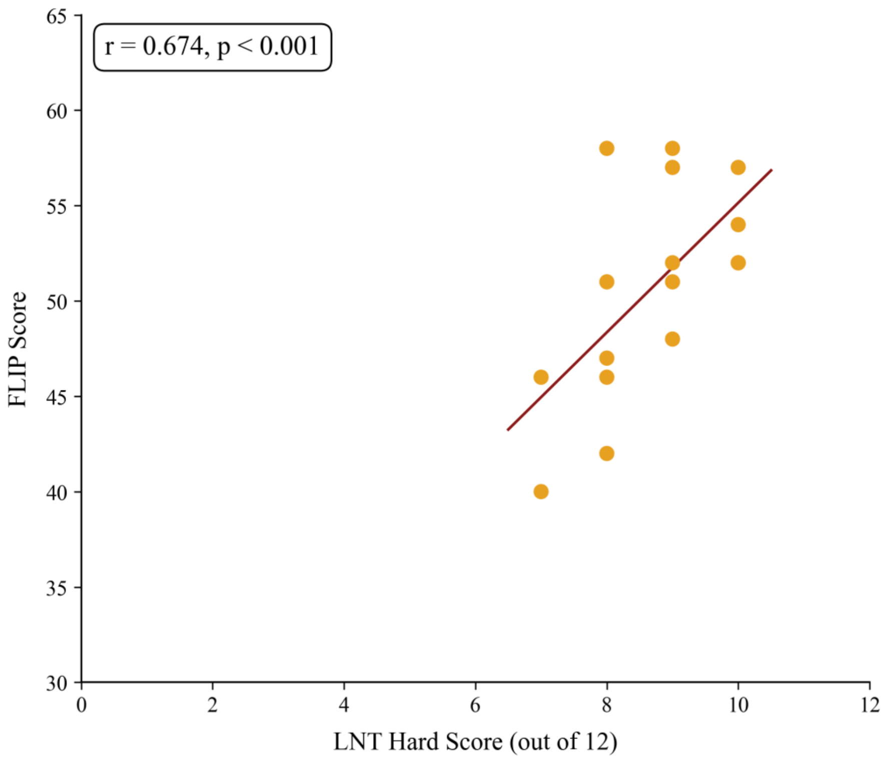


Note. Depiction of LNT easy scores (out of 13; x-axis) plotted against FLI-P total scores (out of 64; y-axis). Solid lines represent ordinary least squares regression lines. Pearson product-moment correlation coefficient (r) and two-tailed exact p-values are presented.

4.4b Correlation of LNT Hard and FLI-P.

A statistically significant, moderate-to-strong positive correlation was also found between LNT Hard scores and FLI-P scores, ($r = .650$, $p = .001$) (Dancey & Reidy, 2007). This pattern suggests that, regardless of the level of lexical competition in the LNT stimuli, both LNT components relate to functional listening at a similar level. The scatter plot in Figure 7 depicts the distribution of LNT Hard and FLI-P scores across participants.

Figure 7. *Scatter Plot of LNT Hard Speech Identification Scores and FLI-P Scores*



Note. Depiction of LNT hard scores (out of 12; x-axis) plotted against FLI-P total scores (out of 64; y-axis). Solid lines represent ordinary least squares regression lines. Pearson product-moment correlation coefficient (r) and two-tailed exact p-values are presented.

Summary of Results

In summary, key findings that emerged from the analyses were,

- Speech perception performance is significantly higher in LNT than in OWT.
- Speech perception performance was significantly higher for LNT easy than for LNT hard.
- A significant strong positive correlation was obtained between OWT and FLI-P as well as LNT and FLIP.

- LNT easy and LNT hard were moderate to strongly correlated with FLI-P.

CHAPTER 5

DISCUSSION

The present study examined the relationship between speech-perception performance across: OWT and LNT with functional listening outcomes in cochlear implant users. The findings revealed that speech perception performance significantly higher on the LNT than on the OWT. The OWT, LNT total, LNT easy, and LNT hard scores showed significant positive correlations with FLIP. The strongest correlation was observed with OWT.

This chapter is organised into the following sections

5.1 Scores of Speech perception tests.

5.2 OWT and FLIP correlation.

5.3 LNT and FLIP correlation.

5.1 Scores of Speech perception test

The present findings revealed a clear and statistically significant difference in speech perception performance between the two tests. Participants had a mean LNT score that was significantly higher than the mean OWT score. *Since, a significant difference was observed between the two speech perception measures, the null hypothesis* $1H_0$ *was rejected*.

The pattern of LNT scores being better is consistent with the theoretical basis on which the LNT was designed. The LNT uses simple and age-appropriate words, which can be grouped into those that have low-frequency and high-frequency words. According to Kirk et al. (1995), LNT have phonological neighbourhood density, meaning that the easy list of words will have minimal competitive activation, making it less cognitively demanding. On the other hand, the OWT involves the presentation of balanced phonetic words, but the child is not presented with a restricted choice, hence having to use memory resources and unrestricted access to vocabulary. This task is more aligned with natural listening, leading to poorer performance.

Further it was found that children had significantly better performance on LNT easy compared to LNT hard. This finding supports the prediction made by the Neighbourhood Activation Model proposed by Pisoni and Luce (1987**).** Lexically easy words are frequent and make them simple for the brain to retrieve, whereas lexically hard words are rare and sound similar to many others, creating mental competition to the listener. Such a division has an additional implication in the case of children with cochlear implants, because spectral and temporal deficits in the auditory perception of sounds result in difficulties in making precise phonemic discriminations (Kirk et al., 1995; Kant & Banik, 2017). As LNT easy has sparse neighbourhood, it reached ceiling effect which in turn lead to increased LNT easy scores. However, LNT hard due to its complexity scores were lesser. Since, there was ceiling effect of LNT easy there was a significant increase in LNT total scores over OWT.

5.2 OWT and FLI-P correlation

Both OWT and LNT had statistically significant strong positive correlation with FLIP. *Hence, the null hypothesis $2H_0$ was rejected.* However, OWT showed the strongest and statistically significant positive correlation with FLI-P scores indicating that children who performed better on the OWT demonstrated stronger functional listening abilities in everyday communicative environments. This strong association is consistent with the processing demands imposed by each measure. OWT require the child to identify spoken words from an internal response set, engaging phonological working memory, lexical access, and the integration of auditory cues without any external cues (Tyler, 1993). These are precisely the skills that enable effective listening in naturalistic environments, at home, in the classroom, and in social interactions, where acoustic signals are unpredictable and visual support may be limited. Geers et al. (2003) reported that word and sentence recognition tasks engage a broader range of auditory-linguistic and cognitive capacities than structured tasks, making open-set measures more sensitive indicators of the abilities that children rely on in real-world communication.

5.3 LNT and FLI-P correlation

There was a significant strong positive correlation between LNT total scores and FLI-P scores, which suggests that children who obtained higher results on the LNT test demonstrated better functional outcomes on the FLI-P test. The relation between the two tests was found to be quite high and statistically significant. However, it did not seem as strong compared to the OWT and FLI-P correlation. According to research, the LNT test has a structured presentation and use familiar words in a quiet listening condition which may enable children to recognize words accurately without having to activate the whole array of auditory-linguistic functions involved in everyday listening (Kant & Banik, 2017). Svirsky & Holt (2008) reported similar finding suggesting that an easier test of speech recognition could not provide auditory system with a sufficient amount of challenges to prepare it for more complex listening situations. Higher LNT performance was due to ceiling effect seen in LNT easy which may overestimate a child's listening in real world communication settings, which is likely why the LNT with FLI-P correlation, though meaningful, was lower than the OWT with FLI-P correlation in the present study.

For further analysis, the LNT subcomponents were examined separately. Both LNT Easy and LNT Hard showed moderate-to-strong, statistically significant positive correlations with FLI-P scores. The correlation coefficients for OWT and FLI-P were consistently higher than the LNT easy and hard words correlation

The correlation between LNT total scores and FLI-P scores was also statistically significant and positive. However, this correlation was relatively weak compared to OWT. The two components of LNT category that is LNT Easy and LNT Hard are different phenomena and address different areas. LNT Easy has sparse neighbourhood and is therefore more likely to achieve the ceiling (Zaltz et al., 2020). The LNT Hard being difficult and have complex structure had resulted in lower scores. However, the total LNT scores are higher since LNT Easy had ceiling effect and hence it did not capture as efficiently as OWT on auditory processing in the real-world listening situations (Spitzer et al., 2024).

From a clinical perspective, the findings strongly support OWT testing in cochlear implant evaluation when the objective is to estimate functional listening ability in everyday communication environments. Although the LNT remains a valuable tool for monitoring auditory progress and for assessing lexical processing in children, the open-set measure appears to provide a more representative index of a child's practical communication ability.

CHAPTER 6

SUMMARY AND CONCLUSION

Cochlear implantation has aided auditory rehabilitation for children with hearing loss, providing access to spoken language that would otherwise be unavailable. The clinical evaluation of cochlear implant (CI) outcomes in children has centred on speech perception testing conducted under controlled conditions. However, such assessments may not adequately capture a child's true listening competency in the dynamic, unpredictable acoustic environments of everyday life.

Speech perception ability, particularly OWT, has long been considered a primary indicator of CI outcome. OWT require the child to identify spoken words without a predetermined response set, drawing instead on auditory memory, lexical knowledge, and cognitive processing abilities that are fundamentally engaged in real-world listening (Geers et al., 2003; Kirk et al., 1995). The Lexical Neighbourhood Test (LNT), developed by Kirk et al. (1995) and adapted for Kannada-speaking children by Apoorva and Yathiraj (2012), extends this evaluation by assessing word recognition that accounts for lexical frequency and neighbourhood density. Specifically, the LNT distinguishes between lexically easy words residing in sparse phonological neighbourhoods and lexically hard words surrounded by many phonetically similar competitors.

Despite the clinical utility of these measures, their functional listening in natural environments has not been fully established for CI users in the Indian linguistic context. Functional listening evaluates the child's capacity to use auditory information in real-world communication settings such as home, school, and social settings (Davis et al., 2022). Understanding how well clinical speech-perception scores predict real world auditory and communication outcomes is, therefore, critical for refining audiological assessment protocols and guiding rehabilitation planning in this population.

The present study aimed to evaluate the relationship between speech perception test performance and functional listening outcomes in paediatric cochlear implant users. The study had two objectives: (1) To compare speech perception performance between OWT and the LNT in children using cochlear implants, and (2) to investigate the association between functional listening outcomes, as measured by the FLI-P, and performance on both OWT and the LNT, including its Easy and Hard subcomponents.

The higher LNT scores were obtained compared to OWT in the present study. Because the LNT employs words familiar to young children and categorises them by lexical neighbourhood density, the easy sub-list presents words with minimal phonological competition, reducing the cognitive demands of word retrieval. This structural characteristic facilitates higher accuracy and reach ceiling but may not fully reflect the broader auditory-linguistic processing required in everyday listening.

To examine the relationship between speech perception tests and functional outcome measures, a Pearson product-moment correlation analysis was conducted. OWT scores demonstrated the strongest correlation with FLI-P scores. This strong positive association indicates that children who performed better on the OWT also demonstrated higher functional listening performance in everyday environments. This pattern is consistent with the findings of Geers et al. (2003) and Wie et al. (2010), who observed that OWT engage auditory-linguistic processing skills that closely mirror the demands of real-world listening.

LNT total scores were also significantly and positively correlated with FLI-P scores. However, this association was comparatively weaker than that observed for the OWT.

Among the LNT subcomponents, LNT Easy and LNT Hard are two different phenomenon which tap different aspects, that is LNT easy due to its sparse neighbourhood reaches ceiling whereas LNT hard due to its complex structure and less familiarity may lead to low scores. But the overall scores of LNT are higher due to ceiling effect achieved by LNT easy component hence it does not capture well. The auditory processing in real world listening situations even though if the scores of LNT are higher than OWT.

The present study concludes that both OWT and LNT speech perception test performance and functional listening outcomes in cochlear implant users are meaningfully related. However, the OWT showed a strongest correlation co-efficient with FLI-P scores compared to LNT, suggesting it is a more sensitive predictor of functional listening ability in everyday life. Both LNT Easy and Hard subcomponents showed moderate-to-strong, statistically significant correlations with FLI-P, confirming that all speech perception measures assessed are clinically relevant, but to varying degrees.

Implications of the present study

1. Both LNT and OWT are strongly associated with functional listening ability, the open set test had a higher correlation coefficient. This has clinical utility in selecting the speech-perception test that best reflects real-life listening ability for Kannada speaking children.
2. OWT can be used to assess the real-world communication abilities of children with CI.

Limitations of the Present Study

1. The study included only 22 participants, which may limit the generalisation of the findings to a larger population.
2. The present study is a cross-sectional design, collecting data at a single point in time. This does not track progress over time. Hence, longitudinal follow-up of the same children would be necessary to understand how these relationships unfold.
3. The study is limited to Kannada language tests and cannot be generalized to other Indian language.

Future Research Directions

1. Future studies should include a larger sample to improve reliability and generalizability of the findings..
2. Further study may examine the relationship between speech perception and other areas such as language development, academic performance and social communication.
3. Longitudinal research can help understand how speech perception and functional listening improve over time with continued CI use and rehabilitation..
4. Further studies to be done in other Indian languages.

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