DEVELOPMENT AND VALIDATION OF RETROFLEX STOP LOADED PICTURE STIMULUS FOR SPEECH SOUND CORRECTIONS IN MALAYALAM

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(Speech -Language Pathology)

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MANASAGANGOTHRI, MYSORE – 570006

June- 2026

CERTIFICATE

This is to certify that this dissertation entitled **"Development and Validation of Retroflex Stop Loaded Picture stimulus for Speech Sound Corrections in Malayalam"** is a bonafide work submitted in part fulfillment for the Degree of Master of Science (Speech-Language Pathology) of the student Registration Number P01II24S123030. This has been carried out under the guidance of the 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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This is to certify that the dissertation entitled **“Development and Validation of Retroflex Stop Loaded Picture stimulus for Speech Sound Corrections in Malayalam”** is the result of my own study under the guidance of **Ms. Sindhusha Chandran**, Assistant Professor of Speech Sciences, Department of Speech-Language Sciences, All India Institute of Speech & Hearing, Mysuru and co-guidance of **Dr. Prithi Venkatesh**, Associate professor of Special Education, Department of Special Education, All India Institute of Speech & Hearing. It has not been submitted earlier to any other University for another Diploma or Degree award.

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INTRODUCTION

Speech intelligibility is defined as the degree to which listeners can comprehend and interpret spoken utterances produced by speakers (Dodd, 2014). It is widely considered a fundamental element for successful communication, as it influences a speaker's social, academic, and professional functioning. Intelligible speech is critical for successful interpersonal communication, and any deviations can negatively impact a child's communicative competence and overall quality of life (McLeod et al., 2012). Speech intelligibility develops with age, and all children are typically intelligible to strangers by 4 years old (Neenu & Sreedevi, 2011). However, reduced speech intelligibility is often associated in various aetiologies such as hearing impairment, cerebral palsy, intellectual disorders, cleft lip and palate, etc. Speech sound disorders (SSDs) are the term identified for the broad category of difficulties that includes both articulation and phonological deficits, causing inaccuracy in speech sound production, affecting speech intelligibility (ASHA, 2021).

Speech sound disorders are commonly seen among preschool and school-age children, with a prevalence rate of 3.4%–8% (Eadie et al., 2015; Law et al., 2000). SSDs are broadly categorized into articulation disorders, which refer to motor-based challenges in the accurate production of specific sounds, and phonological disorders, which involve rule-based errors in the underlying phonological system (Dodd, 2014; Namasivayam et al., 2020). Children diagnosed with SSDs often present with substitutions, omissions, distortions, and additions of speech sounds, which can result in reduced speech intelligibility and hinder communicative participation (ASHA, 2021). The aetiology of SSDs is multifactorial and includes structural anomalies, cognitive factors, neuromotor impairment, and sensory deficits. Among these factors, hearing impairment (HI) is considered one of the major causal contributing factors of deviancy in speech intelligibility (McLeod & Baker, 2017).

Hearing impairment is one of the major sensory disabilities globally, with approximately 34 million children affected by hearing loss worldwide (WHO, 2021). Children with hearing impairment are vulnerable to delays and deficits in speech sound development because adequate auditory feedback is essential for both the initial learning and monitoring of speech production (Moeller et al., 2007; Ertmer & Goffman, 2011). The acquisition of a complete and accurate phonological system is a primary challenge for children with congenital hearing loss. Even mild-to-moderate degrees of hearing loss interfere with the typical developmental trajectory of phonological acquisition, causing persistent speech errors in school-age children and beyond (Norbury et al., 2016; Sarant et al., 2015). Moderate to profound degrees of loss, in particular, show a distinctive pattern of articulation errors that includes place of articulation substitutions, omissions of consonants, voicing errors, especially in word medial and final positions, which significantly reduce conversational intelligibility (Sreedevi & Mathew, 2022).

Historically, children with HI have been fitted with conventional hearing aids, which amplify sound and enhance access to speech sounds across different frequencies. While hearing aids have been shown to improve speech and language development, their efficacy depends on degree of hearing loss; children with severe to profound sensorineural hearing loss often receive limited benefit from amplification alone (Bagatto et al., 2016). The advent of cochlear implantation (CI) has substantially transformed the habilitation strategy for this population. In cochlear implantation, the damaged hair cells are bypassed directly by stimulating the auditory nerve through an electrode array, thereby restoring speech perception even in cases of profound loss (Niparko et al., 2010). Early implantation within the first 12–18 months of age has been shown to yield better outcomes in terms of speech perception, expressive language, and articulation ability compared to later implantation (Sharma et al., 2002; Geers et al., 2003). It was further revealed that children implanted in infancy result in better fundamental frequency control and articulatory performance compared to older recipients.

Despite the immense benefits of cochlear implantation, there is evidence that children fitted with cochlear implants continue to exhibit speech sound errors and impaired speech intelligibility compared to their typically developing children (Flipsen, 2008; Moeller et al., 2010). Numerous studies on the speech of CI users have documented difficulties, primarily delayed access to oral language during critical periods of auditory development. Lighterink et al. (2025) reported that paediatric CI users produced unique and highly variable consonant patterns that may compromise overall speech intelligibility. The researchers identified substitutions as the most frequent error type, with place of articulation errors occurring more frequently than manner or voicing errors. Specifically, they noted that sounds that require complex, invisible articulatory gestures, such as retroflex consonants, remain among the most frequently misarticulated phonemes by this population, due to limited auditory feedback as well as a high degree of fine motor control needed to produce them.

The successful mastery of speech sounds in these children depends heavily on both auditory feedback and the visual prominence of the articulatory gestures. Research demonstrates that phonemes with clearly visible places of articulation, such as bilabials and labiodentals, are produced more frequently and accurately after cochlear implantation (Chin & Pisoni, 2000). In contrast, sounds that require complex, non-visible articulatory gestures remain a persistent clinical challenge. Retroflex consonants constitute one of the most demanding phonetic categories in this respect. This is because the production of retroflexes requires fine articulatory gestures involving a precise retraction of the tongue body and an upward or backward movement of the tongue blade against the post-alveolar or palatal region

(Luo, 2020). Limited channel resolution in cochlear implants often obscures the fine spectral differences and high-frequency acoustic cues needed for perceiving these retroflex gestures.

This articulatory and perceptual challenge is particularly critical in Dravidian languages like Malayalam, which rely heavily on alveolar, retroflex, and dental contrasts for semantic distinctions. Recent exploratory studies on the speech profiles of Malayalam-speaking children with hearing impairment show that substitution errors are the predominant error type, with place of articulation errors occurring more frequently than manner errors. In this population, retroflex consonants are difficult to acquire and are often substituted with dental or velar sounds (Sreedevi & Mathew, 2022). Among the retroflex sounds, the retroflex stop is the most studied, with the third formant frequency F3 playing a significant role in differentiating retroflex sounds from other places of articulation. However, there is a lack of acoustic data on retroflex sounds other than stops, which can challenge evidence-based assessment and intervention (Chawla & Meigh, 2020).

Although this clear phonetic difficulty, traditional motor-based interventions often use repetitive drill-based tasks that isolate phonemes without providing a meaningful communicative context. Naturalistic meaningful contexts, such as carefully designed, theme-based picture stimuli, offer an engaging framework that helps overcome challenging and "invisible" sound productions to meaningful linguistic units. When these stimuli are loaded with target phonemes, they provide ample production practice of that specific target in a natural and meaningful manner, compared to meaningless drills. This approach employs multimodal input, which is beneficial for CI users who compensate for auditory limitations by integrating visual information from the stimuli during speech processing, thereby enhancing the acquisition of phonological distinctions that are difficult to acquire through auditory cues alone (Ortmann et al., 2017). This integration of both visual and auditory information is crucial, as studies demonstrate that CI users' speech perception and production abilities are significantly related to their capacity to integrate multiple sources of speech information.

Currently, there is a profound lack of standardized, evidence-based materials specifically tailored for complex, late-acquired phonetic categories like retroflex stops in Indian languages. To address this gap, developing culturally and linguistically relevant therapeutic materials, such as phoneme-loaded articulation stories illustrated through web-based applications or artificial intelligence, could significantly enhance speech sound correction and generalization to natural speech contexts. Moreover, such resources could provide real-time visual feedback and structured practice in connected speech that is often missing from traditional interventions, moving beyond isolated sound practice to functionally integrate target phonemes into contextualized communication (Daliya, 2025). This multisensory approach, integrating auditory and visual inputs, has also shown to improve language outcomes in CI recipients and is crucial given that spoken language perception is inherently multimodal (Ortmann et al., 2017)

Therefore, the current study aims to bridge this gap by developing and validating culturally and linguistically appropriate retroflex stop-loaded picture stimuli (/ʈ/ and /ɖ/) for speech sound corrections. By creating specialized, naturalistic tools for Malayalam-speaking children fitted with cochlear implants, this research seeks to improve their articulatory accuracy and foster generalization to connected speech, ultimately enhancing functional communication outcomes.

Need for the study

Literature review in the area thus revealed that children with hearing impairment often exhibit speech sound errors. They tend to exhibit persistent difficulties in producing specific category of phonemes due to poor auditory feedback and limitations in perceiving fine phonetic differences, leading to poor speech intelligibility. Targeting these frequently misarticulated speech sounds individually is a necessity to improve speech intelligibility in children with hearing impairment (Sreedevi & Mathew, 2022). The production of retroflex stops is difficult for this population, especially in connected speech, where higher linguistic load and contextual coarticulation requirements may pose additional effects on accuracy.

While there are traditional intervention strategies to elicit and correct speech sound productions at word-level, there is a lack of evidenced based stimuli materials available to target training in connected speech. Traditional therapy techniques employ phonetic placement, minimal pair therapy, and auditory training that uses repeated word-level drills with flashcards or text that are monotonous and less engaging. Though these techniques are best suited for older children, picture-based materials that are loaded with targeted phonemes not only increase interest, engagement, and interactivity in younger children but also provide increased contextual opportunity to elicit the target sounds at the sentence level before moving to the conversation level. This will ensure that the target sounds are well-trained in connected speech.

Retroflex sounds are frequently misarticulated in children with hearing impairment because they require precise lingual positioning in addition to accurate auditory discrimination. Since words containing the sounds /ɭ/, /ɳ/, and /r/ are limited, picture stimuli will be developed specifically for the sounds /ʈ/ and /ɖ/ in this study. Studies revealed that /ʈ/ exhibited place errors in both initial and medial positions (100%), and its voiced counterpart /ɖ/ showed place-voicing errors in the initial position (100%) in Malayalam-speaking children with hearing impairment (Sreedevi & Mathew, 2022). /ʈ/ and /ɖ/were most frequently substituted with velar sounds in the initial position. The mean error percentages were notably high ie., 35.71% for /ʈ/ and 50.79% for /ɖ, highlighting the clinical significance of targeting these sounds for intervention. However, there are no existing stimuli resources that has been validated for articulation interventions to remediate retroflex speech sound corrections. A picture stimulus for articulation intervention of five sibilant sounds (fricatives /s/, /ʃ/, /ʂ/ and affricates /ʧ/, /ʤ/) was validated in Malayalam for children with speech sound disorders (Daliya, 2025). The development and utilisation of such materials are essential for improving interventions by integrating treatments with real-life communication scenarios.

Aim

To develop and validate retroflex stop-loaded (/ʈ/ and /ɖ/) picture stimulus for speech sound corrections in Malayalam.

Objectives

The following are the objectives of the study

1) To develop retroflex stop-loaded picture stimulus for speech sound corrections in Malayalam for children with hearing impairment fitted with cochlear implant.
2) To validate retroflex stop-loaded picture stimulus for speech sound corrections in Malayalam in children with hearing impairment fitted with cochlear implant.

Chapter II

REVIEW OF LITERATURE

The development of culturally and linguistically appropriate intervention materials is an emerging and critical focus within speech-language pathology, particularly for Dravidian languages such as Malayalam. Recent empirical work has successfully demonstrated the clinical value of phoneme-specific tools; for instance, the development and validation of sibilant-loaded picture stimuli proved highly effective in correcting articulation errors among Malayalam-speaking children with speech sound disorders (Daliya 2025). While this foundational research establishes the efficacy of using naturalistic, theme-based visual stimuli for the sibilant sound class, a significant gap remains in addressing other complex phonetic categories and specialized clinical populations. Retroflex stops, which demand precise and complex articulatory placement, pose a persistent challenge, particularly for children undergoing auditory rehabilitation via cochlear implants. To contextualize the clinical necessity of developing retroflex stop-loaded picture stimuli tailored for this specific demographic, the following sections will review the existing literature regarding speech intelligibility, the articulatory complexities of retroflex acquisition, and the unique speech sound profiles of children with hearing impairment (HI).

2.1 Speech intelligibility

Speech intelligibility, which refers to the extent to which a listener comprehends a person’s speech, and is a key outcome in spoken language development (Spencer et al., 2011). It is crucial for effective communication and a significant factor in speech pathology. Development in children's speech intelligibility is a continuous process. Vocal exploration, babbling, and word approximation begin in the first year of life and continue throughout childhood until the child can produce clear, adult-like utterances. Much attention has been paid to the acquisition of individual speech sounds. Research suggests that most English-speaking children can produce the majority of sounds with some accuracy by the time they are 5 or 6 years old, even though mastery of all speech sounds is expected to take place until around age 8 (Sander, 1972). According to Divya (2010), Malayalam speaking children acquire all the vowels and singleton consonants by 4 years of age, and their speech becomes intelligible to a stranger.

The factors that influence speech intelligibility are mainly speaker and listener-related (McLeod, 2020). Age, gender, or presence of any communication disorders are speaker-related factors (Lagerberg et al., 2014; McLeod, 2020). The relationship between the listener and the speaker, along with the speaker's language, is a listener-related factor that can influence intelligibility (Baudonck et al., 2009; McLeod, 2020; van Doornik et al., 2018). Additionally, linguistic tasks and contextual elements can also impact how well speech is understood (McLeod, 2020).

2.2 Early phonetic repertoire and acquisition of consonants

A majority of native English-speaking children master the accurate production of all vowels and consonants by the age of eight (Dodd, Hulm, Hua, & Crosbie, 2003; James, 2001; Smit, 1993a, 1993b; Templin, 1957). According to Kent (1992), back vowels, liquids, and fricatives are produced later as they require more control of the tongue. Anterior sounds are typically learned before posterior sounds, and unvoiced consonants are typically produced more accurately than voiced consonants (Joy, 2020).

According to Indian studies, Maya and Savithri (1990) researched on acquisition of speech sounds in three to seven-year-old Malayalam-speaking children. They found that all vowels were acquired by the age of three, and the majority of consonants, except aspirated phonemes, fricatives, the lateral /l/, the flap /r/, and the trill /r/, were also learned by this period.

The order of acquisition follows unaspirated stops, followed by aspirated stops, fricatives, and affricates. Malayalam-speaking children learn all consonants except fricatives, laterals, and aspirants by the age of four (Neenu & Sreedevi, 2011). In terms of place of articulation, bilabials, labiodentals, dentals, and velars were acquired earlier than alveolars, palatals, retroflexes, and glottal consonants (Neenu & Sreedevi, 2011).

2.3 Articulatory complexity of retroflex stops

Retroflex stops are the consonants produced by curling the tongue tip backwards to make contact with the palatal portion of the oral cavity. Articulatorily, retroflexion is defined as a place of articulation in which the tip of the tongue is curled back and placed posterior to the alveolar ridge (Stevens & Blumstein, 1975). It differs widely from pre-alveolar to nearly post-palatal depending on how much the tongue is curled (Dave, 1977; Dixit, 1990; Dixit & Flege, 1991; Firth, 1957; Ladefoged & Bhaskararao, 1983; Svarny & Zvelebil, 1955). Such variation can be observed across individual speakers, phonetic environments, dialects, and languages. Vowel context influences retroflexion, with front vowels tending to reduce retroflexion while it increases for back vowels (Dave, 1977; Dixit, 1990; Dixit & Flege, 1991). Dental and retroflex stops in English are allophonic variations of the alveolars. Likewise, aspirated and unaspirated stops occur frequently in English, but the usage of aspiration does not help in distinguishing the speech sounds (Delattre, 1966).

As retroflex requires a complex tongue position, they are typically acquired later in development than simpler sounds such as bilabials (/p/, /b/), nasals (/m/, /n/), and dentals. A cross-linguistic study by McLeod and Crowe (2018) on 27 languages reported that posterior consonants, including retroflexes, are generally mastered later than anterior consonants. Maya and Savithri (1990) reported that retroflex sounds were acquired later compared to bilabials, labiodentals, dentals, and velars in Malayalam-speaking children aged 3-7 years, which highlights the complexity in the articulation of retroflex stops, especially in Dravidian languages.

2.4 Disorders of speech intelligibility

Paediatric communication disorders that compromise on speech intelligibility include cerebral palsy, intellectual disorder, cleft palate, childhood apraxia of speech or hearing impairment. Office of the Registrar General and Census Commissioner, India (2011) reported that hearing impairment affected 18.9% and speech impairment affected 7.5% of the disabled population. Furthermore, All India Institute of Speech and Hearing (AIISH) report on the Prevention of Communication Disorders (POCD) school screening program in Mysuru found that 13.3% of screened school children had communication disorders. Hearing abnormalities were found to be more prevalent among individuals identified as at-risk (7.3%) than speech language impairments (6.0%). Among the 20424 children evaluated, 1492 (7.3%) had hearing impairments, which included both hearing loss and middle ear conditions such as impacted wax, tympanic membrane abnormalities, otitis media, and so on. The incidence of hearing loss was higher bilaterally (65.62%) than unilaterally (34.38%). Of these children, 20.9% had only mild to profound hearing loss, which indicates more of sensorineural type in nature, without any middle ear conditions; 11.9% children had only middle ear issues and 67.2% had both hearing loss and middle ear conditions (Sreedevi et al., 2022). These findings highlight the critical need for systematic screening and early intervention for intelligibility issues across the country.

Hearing impairment is the most common sensory impairment affecting individuals of all ages worldwide (Newsted et al., 2020). The World Health Organisation (WHO, 2021) estimates that 1.5 billion people globally have hearing loss, with 34 million children requiring rehabilitation. Numerous studies reported that speech intelligibility is highly impacted by hearing impairment, and that age-related improvements are limited (Svirsky et al., 2000). Reduced intelligibility has an impact on social perception and participation in addition to communication. Freeman (2018) observed that typically hearing individuals received more positive ratings for speech intelligibility compared to those with cochlear implants. Similarly, Most et al. (2012) found that among children with hearing impairments, higher intelligibility was linked to enhanced social skills and a reduction in feelings of loneliness.

The major goal of a speech language pathologist (SLP) in intervention for children with hearing impairment is to improve intelligibility in connected speech (Ertmer, 2011). This is challenged by limitations in their speech perception. These limitations can be due to delayed phonological processes or vowel inaccuracies. So overall, all these factors can make the speech unintelligible (Stefánsdóttir et al., 2024).

2.5 Speech sound errors in children with hearing impairment

This persistent difficulty in producing speech sounds that hinders effective verbal communication or speech intelligibility is classified under speech sound disorder (SSD) (American Psychiatric Association, 2013). According to the American Speech Language and Hearing Association (ASHA), SSDs are defined as any issues with respect to phonological encoding, motor production, and perception of speech sounds and speech segments or a combination of all of these issues. In general, SSDs can be of two types: articulation and phonological errors. Articulation errors are the motor impairment to produce speech, while phonological errors involve difficulty in recognising and using proper speech patterns. According to Dodd et al. (2018), phonological errors can result from a disorder when the speech patterns are non-developmental or inconsistent, or from a developmental delay when the speech patterns resemble those of a younger, typically developing child. According to St Johns et al. (2020), the most common type of SSD in children with hearing loss is phonological delay.

Children with HI are more likely to develop speech sound disorder and they frequently exhibit errors in the production of vowels and consonants, specifically substitutions, distortions, and omissions. Omission and substitution errors have the greatest effects on overall speech intelligibility (Boudonck et al., 2011; Moeller et al., 2010; Ellis, 2009). Wiggin et al., (2013) reported that by around age seven, roughly 50% of English-speaking children with HI are able to produce all consonants correctly. A study by Geers and Tobey (1992) reported a decrease in speech sound errors, including consonant substitutions, distortions, and omissions, after cochlear implantation. Children with cochlear implants perform better than their peers with hearing aids in terms of speech perception and language abilities (Miyamoto et al., 1997; Tomblin et al., 1999). The most common speech sound errors were fricatives, affricates, liquids, semivowels, plosives, and consonant blends (Abraham, 1989). These errors have been reported at the segmental level (Levitt & Stromberg, 1983; Paterson, 1994).

2.6 Assessment in children with speech sound disorders

A comprehensive assessment is necessary for the accurate diagnosis and treatment of speech sound disorders. Commonly two sampling methods used in speech sound assessment: spontaneous speech sampling, where a child's natural conversation is recorded to evaluate intelligibility and error patterns, and single word sampling, where the child names or repeats objects or pictures to evaluate their production of individual phonemes. According to Xue et al. (2023), meaningful sentences can be utilized in place of word lists to better depict speech intelligibility, aid in precise diagnosis, and help establish articulation goals for therapy.

Multiple domains are assessed as part of a comprehensive assessment. Phonological process analysis identifies pathological patterns, while articulation tests examine the accuracy of individual phoneme production. In order to determine the prognosis, stimulability testing is used to see if the child can make a sound with adequate assistance. In order to rule out any structural problems, an oral mechanism examination is carried out to evaluate the articulators involved in speech/articulation including the tongue, lips, palate, jaw, and other structures involved in speech or articulation. Lastly, phonological awareness testing assesses a child's capacity to identify and modify sounds within words, which is important for reading and is also linked to speech sound disorders.

2.7 Management approaches for speech sound intervention

SSDs are intervened using a variety of strategies, such as linguistic and motor-based interventions. The idea behind the motor-based approach to SSD remediation is that poor motor skills and reduced perceptual abilities are the root causes of articulation difficulties. Traditional approaches, sensorimotor approaches, multiple phoneme approaches, and paired stimuli approaches are examples of motor-based approaches. In order to improve the precision and clarity of speech output, this approach concentrates on individual sounds and identifies errors in terms of omissions, distortions, and substitutions. On the other hand, the cognitive-linguistic approaches, which includes cycles approach, minimal pair approach, and distinctive feature therapy, focuses on assisting individuals in developing a clear set of phonological principles so they can identify and employ consistent sound patterns in their speech.

In order to address phonological difficulties, the linguistic-phonological paradigm employs a number of methods, including contrast approaches, complexity approaches, the Core Vocabulary Approach, and the Cycles Approach, which focus on the child's internal rule system (Cabbage & DeVeney, 2020). These strategies seek to improve children's capacity to manipulate and consider sounds through metaphonological therapies or to help them become aware of particular contrasts in their language through approaches like minimum pair therapy (Maphalala et al., 2014). By classifying sounds according to their phonetic characteristics, for example, metaphon therapy explicitly seeks to develop children's phonological awareness and enable the generalization of recently learned speech patterns (Bowen, 2015). Alighieri et al. (2023) state that linguistic and phonological strategies are a good way to treat specific populations, but there isn't a lot of evidence to support their use with others, like children with cleft palate.

Clinicians can employ both deep and broad training methods to treat SSDs. While the broad training approach provides simultaneous training for multiple sounds, the deep training method focuses on intensive training for one or more sounds. For therapy to be successful, choosing the right treatment approach is crucial. Children may be candidates for both phonological and articulation-based approaches when speech sound errors occur, based on whether the deficits are linguistic versus motor (Gordon-Brannan & Weiss, 2007). Specifically, articulation focuses on the accurate production of sounds, whereas phonological processes focus on patterns of error based on linguistic rules. No one treatment is shown to always be superior by research; for example, Gierut (1998, 2007) and Dodd et al. (2008) demonstrate only minor differences based on contrasting methods. Typically, clinicians will use an eclectic model which incorporates auditory discrimination, minimal contrasts or phonological awareness-based strategies, depending on the specific child (Joffe & Pring, 2008; McLeod & Baker, 2014).

The best available external research evidence, the clinician's professional knowledge, and the client's and family's preferences and values are all crucial components of evidence-based practice (EBP) in the treatment of speech sound disorders. Bowen (2015) highlights that this paradigm, also known as E3BP, guarantees that treatment decisions are based on scientifically verified procedures that are customized to each patient's needs rather than just tradition or popularity. For instance, according to Bowen's 2015 study, one of the issues that is most controversial is the extensive use of non-speech oral motor exercises (NSOME), such as blowing or sucking. Numerous studies have constantly established that NSOME lack both empirical basis and theoretical foundation. Because improvements in non-speech motions do not translate to speech results, Lof and Watson (2008, 2010) have claimed that these exercises violate task specificity rules.

2.8 Early intervention

For children with hearing impairments, analog hearing aids were the best option in the past. With advances in technology, digital hearing aids, which offer better signal processing, were introduced. However, due to limitations in providing sufficient amplification for hearing and perception, children with severe to profound hearing loss do not benefit from them. To overcome this, cochlear implantation is a better option. CI can produce louder sounds while helping in better speech perception. Studies showing improvements in speech perception and production have significant advantages of cochlear implantation for hearing restoration (Tobey et al., 1994; Osberger et al., 1991).

Early identification and intervention are vital for children with hearing loss to acquire age-appropriate speech and language (Yoshinaga-Itano et al., 1998). Use of amplification technologies, including cochlear implants (CIs) and hearing aids, offers access to sound, and it is found that the earlier the implantation and improvements in technology, the more it improves outcomes in speech and language for children (Kirk et al., 2000; Lenarz, 2017; Shivaprakash, 2019).

At present, the Indian Government strongly emphasizes early implantation programs like the ADIP scheme, offering financial support to enable children to undergo cochlear implants at a young age. These forward-looking initiatives have resulted in a growing number of very young children attending clinics for post-implant therapy, emphasizing the necessity for age-suited intervention strategies. According to Chatterjee et al. (2019) and Mehrotra (2020), the rising prevalence of early implantation highlights the critical need for reliable, standardized diagnostic instruments and rehabilitation methods that are adapted to the developmental stages of these young recipients. The availability of assessment protocols that accurately capture the subtle auditory and linguistic progress in this demographic is crucial because the U.S. FDA guidelines allow cochlear implantation for infants as young as 12 months, and some surgeons are moving forward with implantation even earlier in cases of documented hearing aid inefficacy or heightened risk of cochlear ossification (Nandurkar & Rajani, 2019; Tomblin et al., 2005).

2.9 Naturalistic, contextual, and meaningful intervention strategies

Amplification combined with structured methods, such as Auditory Verbal Therapy (AVT) features, provides substantive support to the child in learning to communicate primarily through audition, which needs speech, language, cognition and audition to develop (Pollack et al., 1997; Estabrooks, 1994; Brennan-Jones et al., 2014).

Naturalistic, play-way, and meaningful intervention are key components of modern AVT strategies for this young post-implant group. Traditional flashcards and tedious drills lack learning in natural, meaningful context, an unnatural isolation of sounds, and a failure to encourage spontaneous language use. Instead of focusing on phonetic drill practice at the word level or in isolation, naturalistic intervention aims to remediate speech sound mistakes in everyday meaningful activities. Units of utterance are a significant predictor of speech intelligibility, and the production of sounds alone may not offer sufficient coarticulation, which in turn impairs speech intelligibility in smaller units (Allison & Hustad, 2014).

According to a 1993 study by Camarata, naturalistic conversation training that uses play-based, descriptive engagement improves speech sound outputs. It is far more realistic and significant to use naturalistic settings and picture description. In clinics, detailed, captivating visuals can be used to effectively recreate a scenario, such as how a parent spontaneously talks to a child about a familiar place, like a park. According to data from a randomized control experiment conducted by Jesus et al. (2019), employing picture-based naturalistic intervention will improve speech sound correction and is on par with conventional articulation treatment. According to the literature, materials like alliterative stories and images that target consonant clusters are being developed (Bowen, 2015), but they are not standardized, used, or supported by empirical data. Additionally, the child may more readily use these abilities in their daily life, and parents relate to this contextual approach much better.

Comparative evidence suggests that phoneme-loaded, contextually embedded materials produce stronger generalization than traditional word-level drill approaches. Communication-based intervention, which situates target sounds within meaningful, has been shown to yield greater carryover to functional communication than repetitive isolated practice (Kempler & Goral, 2011). In the Indian context, phoneme-loaded articulation stories in Malayalam have also been validated for use with children with hearing impairment, with findings indicating higher child engagement and more accurate target word production when phoneme-dense stimuli were used (Chandran & Sreedevi, 2025). These findings collectively support the development of standardized, phoneme-specific intervention materials in regional languages.

Current evidence is lacking, partly because none of the therapy materials related to connected speech are standardised, and they do not regulate the occurrence of speech sounds (e.g. production, co-articulation of sounds). We still need to identify standardised, efficient, naturally occurring options for connected speech practice to support the use of technology and to promote generalisation to the everyday communication situation.

Chapter III

METHOD

The primary aim of the study was to develop and validate retroflex stop-loaded picture stimuli for speech sound correction in Malayalam. The study was conducted in two phases. Phase 1 aimed to develop a retroflex stop-loaded picture stimulus in Malayalam, which was then validated on native Malayalam-speaking children with hearing impairment fitted with cochlear implant who had phonemic level errors in retroflex stops.

3.1 Ethical consideration

The study was conducted following approval from the *Ethical guidelines for bio-behavioural research involving human subjects (Version 2.0)* (All India Institute of Speech and Hearing, 2023). The caregivers of the participants were informed of the procedure and rationale of the study and were assured of the safety and confidentiality of the participants' details. The study was approved by the AIISH Bio Behavioural Ethical Committee (reference: SH/IRB/M.5/SLP.28/2025-26) (Appendix I). Consent from parents/ caregivers of the participants was taken in their native language, after which they were enrolled in the study.

3.2 Participants

Five native Malayalam-speaking children between 4 and 10 years of age were recruited for the study. The language age of >2.0 to 2.6 years in receptive as well as expressive abilities, as measured by the Assessment Checklist for Speech-Language Skills (ACSLS; Swapna et al., 2010), were enrolled for intervention. All enrolled participants were children with prelingual hearing impairment who had undergone cochlear implantation and currently receiving habilitation services at the Institute.

Participant sample was drawn from the Department of Clinical Services (DCS), Aural Rehabilitation Unit (ARU), and Department of Special Education (DSE) at AIISH, Mysuru. Demographic and audiological information, like age of implantation, period of cochlear implant use, and history of speech-language therapy and aural rehabilitation therapy, were documented.

Participant selection criteria

Inclusion Criteria

- Children diagnosed with bilateral severe to profound sensorineural hearing loss by an RCI certified audiologist, and aided with cochlear implants at least in one ear And hearing aids in the other ear.
- Malayalam as their native language.

Exclusion Criteria

- Children who have already attended/ attending articulation remediation of retroflex stops.
- Other co-occurring neurodevelopmental or medical conditions like Intellectual disability (ID), Attention-deficit/hyperactivity disorder (ADHD), Autism spectrum disorder (ASD), Down syndrome (DS), and Learning disabilities (LD).
- Children who have oromotor deficits or structural anomalies impacting speech production.

3.3 Research design

The study utilized a single-subject (ABA) design consisting of a baseline (A), intervention (B), and follow-up (A) phase and included participants who met the inclusion criteria. This design is commonly used in intervention studies because it helps evaluate the effects of intensive therapy within small sample sizes.

During the baseline assessment, all participants underwent a detailed evaluation using one of the developed stimuli to identify their errors at the phrase/sentence levels. Two baseline assessments were carried out on two consecutive days to ensure reliability and stability of the participants baseline performance before initiating the intervention. Following the baseline assessment, articulation therapy using remaining three stimuli was provided to the participants. This therapy specifically targeted the sounds /ʈ/ and /ɖ/, aiming to correct and improve the clarity of retroflex stop production. During the intervention, two mid-intervention assessments were carried out to monitor the participant's ongoing progress. After completing the intervention phase, two post-intervention assessment was conducted to measure the immediate effects of the treatment. Additionally, two follow-up assessments were carried out one week and two weeks after the intervention to evaluate the retention and generalization of the target speech sounds.

3.4 Materials used

1. Revised Malayalam Articulation Test (MAT-R):

Revised Malayalam Articulation Test- (Neenu et al., 2011) is a standardised test used to evaluate articulation errors in various word positions in Malayalam. The test was administered during the pre-intervention assessment to identify the speech sound errors, and to target the sound for intervention.

2. Assessment Checklist for Speech-Language Skills (ACSLS):

Assessment Checklist for Speech-Language Skills (Swapna et al., 2010) assesses the receptive and expressive abilities of the child. This tool was utilised as a criteria to enrol participants who were beyond the language age of 2 years to qualify for intervention using connect speech contexts (picture description).

3. Picture stimuli (developed in phase 1 of the study):

From the four sets of picture stimuli in each of the target sound /ʈ/ and /ɖ/, one picture stimuli (one with higher words with target sounds) was selected for assessments during the pre-intervention, during intervention, post-intervention and 2 weeks follow-up. This was to maintain uniformity in the stimuli across all the participants. The remaining three picture stimuli were targeted for speech sound correction during the intervention phase.

4. Audio and video recorder:

All the assessment sessions and intervention sessions were audio-video recorded using a video recorder (model: Sony Camcorder HDR–CX280E) in a speech-language therapy room.

3.5 Qualitative and quantitative analysis

Outcome measures

For the target retroflex stop sounds, a qualitative analysis was done using Place, Manner, Voicing (PMV) and Substitution, Omission, Distortion & Addition (SODA) error analysis. This helped determine the character of participant mistakes throughout the production process. Quantitatively, the errors were analysed by calculating the Percentage of Consonants Correct – Revised (PCC-R, Shriberg et al., 1997) and Percentage of speech Intelligibility.

These measures were taken for each target word in each assessment phase (baseline, intermediate intervention sessions, post-intervention, and follow-up) in order to assess the efficacy of the therapy. The speech samples of each child elicited during picture descriptions in each phase were transcribed phonetically to identify error patterns with respect to SODA errors and PMV parameters.

1. *SODA error analysis*

Substitution, omission, distortion and addition errors were analyzed from the recorded sample of MAT-R (Neenu et al., 2011). MAT-R picture stimuli were presented using power point presentation for the child to name it. For children who had difficulty naming, repetition of the stimulus was used for elicitation of the responses. All the utterances were recorded for later analysis.

Further analysis of the MAT-R responses was carried out to evaluate the place, manner, and voicing characteristics of the child's speech production. The errors observed in the sample were categorized according to articulatory placement (such as bilabial, dental or retroflex), manner of articulation (such as stopping or gliding), and voicing patterns (such as voicing or voiceless).

2. *Percentage of Consonants Correct -Revised (PCC-R)*

PCC-R was calculated by analysing the recorded samples of pre-intervention, mid-intervention, post-intervention and follow up of each participant. The number of consonants correct and total number of consonants were analysed from the connected speech sample to calculate PCC-R.

PCC-R was calculated as below,

$$\left(\frac{\text{Number of consonant correct}}{\text{Number of correct + Incorrect consonants}} \right) \times 100$$

3. *Percentage of speech intelligibility*

Audio recordings of the connected speech sample were analysed to calculate percentage of speech intelligibility. Total number of intelligible words and total number of words were analysed to calculate the percentage.

Percentage of intelligibility was calculated using the following formula,

$$\left(\frac{\text{Number of intelligible words}}{\text{Total number of words}} \right) \times 100$$

3.6 Procedure

The study was carried out in two sequential phases. The initial phase involved the development of retroflex stop-loaded (/ʈ/, /ɖ/) picture stimulus to correct Malayalam speech sound errors. The second phase involved validating the developed stimulus materials on children with hearing impairment fitted with cochlear implants who exhibited phonemic-level errors in retroflex stops.

Phase 1: Development of retroflex stops loaded picture stimulus

In the first stage of the study, a set of picture-based stimuli targeting retroflex stop sounds in Malayalam was developed for the purpose of correcting speech sound errors in children with hearing impairment. The main objective of phase one was to develop picture-stimuli materials with the target retroflex stops /ʈ/ and /ɖ/. A total of eight picture stimuli were developed, with four stimuli for each of the target retroflex stops /ʈ/ and /ɖ/.

First, a list of Malayalam words that included the target sounds was compiled. These words were taken from generic Malayalam children's magazines like ‘Kalikkudukka’, ‘Balarama’, ‘Malarvadi’, and ‘Poompatta’, and Malayalam children's animation like ‘Minnaminni’, ‘Kaathu’, ‘Manjadi’, and ‘Pupi’. The selected target words were carefully chosen to match the developmental level of children between 2 to 6 years of age, easily representable, culturally acceptable, and unambiguous. Common English loanwords used in daily Malayalam usage were also included. Onomatopoeic sounds were also incorporated with specific objects or actions. These are words that imitate real-world noises (like "buzz," "meow," "bow") and are highly useful in speech sound development because they were more engaging, meaningful, and easier for children to imitate and map to real-world referents (Imai et al., 2008; Imai & Kita, 2014).

A total of 91 and 109 words were selected for the phonemes /ʈ/ and /ɖ/, respectively for the development of picture description stimuli. It is observed that a greater number of words were included for the phoneme /ɖ/ when compared to /ʈ/. Malayalam, like other Dravidian languages, shows a higher perceptual salience and functional load for voiced stops compared to their voiceless counterparts in certain phonological environments, although explicit phoneme-level frequency comparisons between /ʈ/ and /ɖ/ are not commonly reported in research studies.

After the list was created, to facilitate contextual applicability and spontaneous elicitation, the chosen words were appropriately categorised under common everyday themes such as bedroom, tea shop, playground, forest, etc., for suitable representation. This thematic representation mainly helped elicit spontaneous speech attempts during therapeutic interaction. Four picture stimuli were designed for the target sound, as mentioned in Table 3.1. The artwork was created by a paid external artist (Art Director, Carmond Infinity Pvt. Ltd). The artist was given the content for the illustration development. Illustrations were digitally hand-drawn by the artist using painting software such as Adobe Photoshop and Procreate, and later, AI tools (Wiscom, Midjourney, and ChatGPT) were incorporated for finer corrections. The pictures were made visually appealing and appropriate for the age group, thus making identification and description of the target words easier. Each picture description stimulus layout included the title of the theme at the top, a list of target words on right side in International Phonetic Alphabet (IPA).

Table 3.1

The theme of picture description stimuli developed with the number of words in each of the target sounds

Target sound	Features	Theme	Total number of target words	Position of target sound		
				Initial syllable	Medial syllable	Final syllable
/ʈ/	Retroflex voiceless stop	The tuition centre	30	12	8	10
		The hotel	27	9	8	10
		The Garden	29	6	14	10
		The utility room	25	12	6	7
/ɖ/	Retroflex voiced stop	The bedroom	35	10	14	11
		The tea shop	34	4	14	16
		The kitchen	33	9	14	10
		The Beach	30	3	15	12

Organisation of content of the developed stimuli:

- *Theme/Topic Heading:* Each illustration were clearly labeled at the top. This help set the context for the picture and supported the organization of target words in familiar and meaningful situations for the child
- *Target Words:* The target words were displayed on the left side of the illustration.
- *Descriptive or Model Sentences:* Simple sentences with the target words are also provided to serve as models for phrase/sentence production, as well as for picture description by the child.

Content validation

After developing the picture stimuli, content validation was conducted by four certified native Malayalam speaking Speech-Language Pathologists (SLPs). A structured feedback-rating questionnaire adapted from the MAFAT-K (Goswami et al., 2011) was utilised to evaluate the relevance, clarity and appropriateness of every stimulus. Each parameter was rated on a five-point scale ranging from very poor to excellent. An inter-rater consistency of 80% or more was considered valid. Based on the suggestions and feedback provided by the judges, lower-rated stimuli were re-modified and the necessary modifications were made to the illustrations. Following the revision, the updated illustrations were subjected for a second round of content validation using the same feedback questionnaire, to confirm that the modifications were adequately addressed. The rating parameters used along with their definitions are provided in Appendix II. The results of the rating obtained from the four judges are presented in Table 4.1.

Table 3.2

Content validation ratings of the developed stimuli by SLPs (n=4)

SI. No	Parameters	Very poor	Poor	Fair	Good	Excellent
1	Simplicity	-	-	-	2	2
2	Familiarity	-	-	-	4	-
3	Size of the picture	-	-	1	3	-
4	Color and appearance	-	-	-	1	3
5	Arrangement	-	-	2	2	-
6	Presentation	-	-	-	3	1
7	Volume	-	-	-	3	1
8	Relevancy	-	-	-	2	2
9	Iconicity	-	-	-	2	2

10	Accessibility	-	-	-	2	2
11	Flexibility	-	-	-	2	2
12	Trainability	-	-	-	1	3

The rating results presented in Table 3.2 indicate that the ratings predominantly fall under the "Good" and "Excellent" categories, with no ratings obtained under "Very Poor" or "Poor" categories. Of the 48 total ratings, 27 ratings came under "Good" category and 18 ratings under "Excellent" category, while 3 ratings were recorded under "Fair" category, specifically for the parameters - size of the Picture and arrangement. 3 of 4 judges rated "Excellent" for color and appearance and trainability. All four judges rated "Good" for familiarity. 3 out of 4 speech-language pathologists rated "Good" for size of picture, presentation, and volume.

The predominantly positive ratings across "Good" and "Excellent" categories can be attributed to several factors. Firstly, the themes selected for the illustrations were concrete and culturally familiar, ensuring clarity and ease of representation for the target age group. Secondly, the target words were carefully chosen to be age-appropriate and familiar for children between 4 to 10 years of age, and the incorporation of onomatopoeic words further enhanced the meaningfulness of the stimuli. Additionally, the sentences used to describe these illustrations can be easily modified according to the child’s age by reducing the mean length of utterance and simplifying the sentence structure, depending on the child’s language level and therapeutic goals.

As the picture development involved the use of artificial intelligence, certain irrelevant and unnecessary elements appeared in the illustrations, which may be one reason why the judges provided fair ratings for size and appearance. These thematically inappropriate elements were removed after content validation as per the recommendations, and instead, other meaningful and representative target words were incorporated.

After content validation, revised materials were pilot tested on three hearing-impaired children with phonemic-level speech sound errors involving retroflex stops. This was to ensure the appropriateness of stimuli elements and utility of the stimuli. Any required modifications were included based on the clinician's observation and the child's reaction to prepare the final set optimal for speech correction.

Table 3.3

Content validation ratings of the developed stimuli by parents (n=3) of children with hearing impairment.

SI. No	Parameters	Very poor	Poor	Fair	Good	Excellent
1	Simplicity	-	-	-	2	1
2	Familiarity	-	-	-	1	2
3	Size of the picture	-	-	-	-	3
4	Color and appearance	-	-	-	-	3
5	Arrangement	-	-	-	1	2
6	Presentation	-	-	-	1	2
7	Volume	-	-	-	1	2
8	Relevancy	-	-	-	-	3
9	Iconicity	-	-	-	-	3
10	Accessibility	-	-	-	1	2
11	Flexibility	-	-	-	2	1
12	Trainability	-	-	-	-	3

The material was subjected to content validation by parents of children with hearing impairment with speech sound errors who had received intervention but were not included in the study. Questions used to obtain feedback from the parents are provided in Appendix III.

Most of the ratings fell within the "Excellent" categories, as shown in Table 3.3. Twenty-seven ratings were categorized as “Excellent,” while nine ratings were categorized as "Good". Parents provided suggestions such as replacing certain English words with commonly used Malayalam words, reducing elements that were difficult for children to identify, and minimizing visual congestion within some illustrations. These suggestions were incorporated into the final set of illustrations, as shown in Appendix IV and Appendix V.

Phase 2: Validation of the developed material

The second phase of the study involved the validation of the retroflex stops loaded picture stimulus for speech sound corrections in Malayalam. The main aim of this phase was to assess the clinical usability of the stimuli in children with hearing impairment fitted with cochlear implants. The validation phase comprised four stages: pre-intervention assessment, intervention, post-intervention assessment, and follow-up. Two intermediate progress assessments were also carried out during intervention phase. One among the four developed picture stimuli was used for all points of assessment, including two baseline assessments in pre-intervention, two intermediate, two post-intervention and two follow-up assessments. The other three illustrations were used during intervention.

All the sessions were video and audio recorded for outcome analysis, including both qualitative and quantitative measures such as Substitution, Omission, Distortion & Addition (SODA) and Place, Manner, Voicing (PMV), Percentage of Consonants Correct -Revised (PCC-R) and percentage of Intelligibility.

Phases involved in validation

i. Pre-intervention (Baseline) assessment – Phase A_1

MAT-R was used to identify the speech sound errors. Children with erred retroflex stop speech sound either /ʈ/ or /ɖ/was selected. Individualized articulation intervention was provided to each of the participant. To confirm the consistency in error patterns, each participant was administered two baseline assessment sessions on consecutive days. One of the picture stimuli (P1) was uniformly used for all the baseline assessments in pre-intervention, between intervention, post-intervention and follow-up after two weeks.

In this phase, the child was shown the picture stimuli, and he/she was asked to describe what was in the picture. The participants did not receive any corrective feedback or verbal cues for the description task during this assessment phase.

ii. Intervention phase:

After the baseline phase, individualized articulation therapy for the sounds /ʈ/ and /ɖ/ was provided to participants. Each child received a total of ten sessions of 45 minutes each. The articulation therapy was administered using the other three retroflex stops-loaded picture stimuli (P2–P4). They were used interchangeably to produce phrase or sentence level production. Graded cues, such as phonemic, syllabic, or word prompts, were provided for the production of the target sound. These cues were progressively reduced to encourage the production of words in sentences to describe the picture. Using the P1 picture stimuli, two intermediate progress assessments were carried out during this phase at predetermined intervals i.e., after 3rd and 7th session.

iii. Post-intervention assessment – Phase A_2

The P1 picture stimuli were used for two post-intervention evaluations as soon as the intervention phase was over, i.e., after the 10th session and 2 days after the 10th session. Participants were asked to describe the picture using the target words without any guidance or cues. Improvements in untrained contexts were evaluated.

iv. Follow-up assessment

Each participant underwent two follow-up evaluations after post-intervention, i.e., after 1 week and 7 days after 1 week. These follow-up sessions used the P1 picture stimuli in all the assessments throughout to assess the maintenance and retention of the learned sound production. During these sessions, no cues or feedback were given. The summary of the validation stage is depicted in the figure 3.1 and timeline of the phases in figure 3.2.

Figure 3.1

Summary of the study phases

PRE-INTERVENTION ASSESSMENT
Administer MAT-R to identify most errored sound (/ʈ/ or /ɖ/),
Two baseline assessment sessions using P1 on consecutive days
Analysis: Percentage intelligibility, PCC-R, SODA & PMV

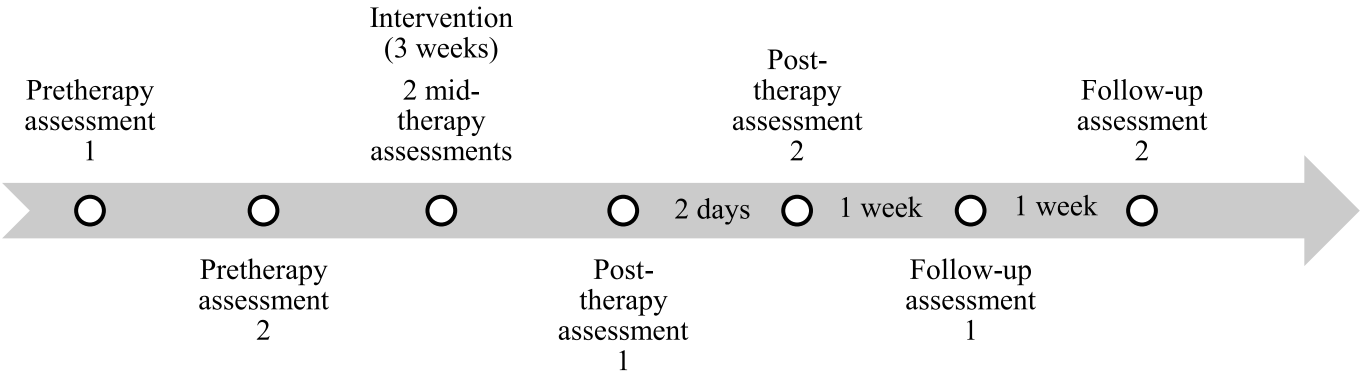
INTERVENTION PHASE
10 sessions of 45 minutes each (3/week),
Individualized therapy sessions using P2-P4: Session 1 to 10
Two between intervention assessments: After 3^{rd} and 7^{th} session
Analysis: Percentage intelligibility, PCC-R, SODA & PMV

POST-THERAPY ASSESSMENT
Two post-intervention assessments using P1: After 10^{th} session and 2 days after the 10^{th} session
Analysis: Percentage intelligibility, PCC-R, SODA & PMV

FOLLOW-UP ASSESSMENT
Two follow-up assessments: 1 week after post-therapy assessment and 7 days after 1 week.
Analysis: Percentage intelligibility, PCC-R, SODA & PMV

Figure 3.2

Timeline of the phases



3.7 Statistical analysis

To check the normality of the scores across all assessment points (pre-intervention, intermediate intervention assessments, post-intervention and follow-up), the Shapiro-Wilk test was utilized. To analyse the qualitative scores and check the effectiveness of this material, descriptive statistics were used. In quantitative analysis, performance across assessment phases was compared using the Friedman test.

To establish intra-judge reliability, 20% of the entire sample (2 baselines, 2 mid-intervention assessments, 2 post-intervention assessments and 2 follow-up assessments of one participant) was reanalysed. Appropriate statistical test was used.

To assess inter-judge reliability, 20% of the recorded responses by two Speech-Language Pathologists (SLPs) who were not acquainted with the participants were examined. Appropriate statistical test was used.

Chapter IV

RESULTS & DISCUSSION

The primary aim of the study was to develop retroflex stop loaded picture stimulus for speech sound corrections in Malayalam speaking children with hearing impairment fitted with cochlear implant and to determine their efficacy in speech sound correction. The study was carried out in two phase: the retroflex stop (/ʈ/ and /ɖ/) loaded picture stimuli in Malayalam was developed and content validated in the phase I, which was then validated on native Malayalam-speaking children with hearing impairment fitted with cochlear implant in phase II.

Five participants were enrolled according to the inclusionary criteria of the study as mentioned in Table 4.1. Across participants, the retroflex stop-loaded picture stimuli were evaluated for its clinical utility and efficacy using repeated baseline, mid-intervention, post-intervention and follow-up measurements (total of eight points in assessment) of articulation outcome measures: phonetic accuracy (PCC-R), speech intelligibility, and error characterization (PMV and SODA). The results are presented as individual case profiles to preserve the single-subject (ABA) design's within-subject resolution, followed by comparison across cases and discussion of factors that may have contributed to the observed changes. Participant-level data illustrate intervention trajectory, error reduction patterns, and maintenance of gains at follow-up.

A total of four picture stimuli were used for each participant. One stimulus with highest target words was utilized for all eight points of assessments to maintain uniformity and other three for speech sound intervention. Before the intervention was initiated, the Malayalam Articulation Test – Revised (MAT-R, Neenu et al., 2011) was used to assess speech sound production in the participants, and the predominant errors were noted. Following this, the intervention phase began. Table 4.1 shows the demographic details, target sound selected for speech sound intervention and type and position of errors of the enrolled five participants.

Table 4.1

Shows the demographic details, target sound for intervention and type and position of errors of five participants

SI. NO	Age/sex	Language Age (in years)		Target sound for intervention (based on MAT-R)	Type of error	Position of error
		RLA	ELA			
1	9 years/M	5.6-6.0	3.0-3.6	/ɖ/	Substitution and Distortion	I, M, F
2	4 years/M	2.7-2.9	2.7-2.9	/ɖ/	Substitution	I, M, F
3	6 years/M	2.10-3.0	2.7-2.9	/ɖ/	Substitution	I, M, F
4	5 years/M	2.7-2.9	2.7-2.9	/ɖ/	Substitution	I, M, F
5	9 years/M	5.6-6.0	3.0-3.6	/ʈ/	Substitution and Distortion	I, M, F

Note. RLA = Receptive language age; ELA = Expressive language age; MAT-R = Malayalam Articulation Test-Revised

4.1. Participant 1

ABC was a 9-year-old child diagnosed with bilateral profound sensorineural hearing impairment, fitted with bimodal hearing (cochlear implant on the right ear implanted at 7 years of age and hearing aid on the left ear since 2 years of age). Both devices were used consistently throughout all assessments and intervention sessions. Child presented with a receptive language age (RLA) of 5.6–6.0 years and expressive language age (ELA) of 3.0-3.6 years in ACSLS during the study enrolment.

The initial assessment using MAT-R revealed substitution of linguo-dental voiced stop /d̪/ in place of retroflex voiced stop /ɖ/ across all word positions with occasional substitution of the retroflex voiceless stop /ʈ/. Distortions of /ɖ/, /ʈ/, /r/ and /ɭ/ were noted in medial and final positions, and omission of /ɖ/ and /ʈ/ were observed at medial positions, especially for multisyllabic words. Speech intelligibility was significantly reduced at the phrase and sentence level with increased errors in multisyllabic words. Thus, retroflex stop /ɖ/ was selected for intervention for ABC. The picture stimulus "Bedroom" was selected for pre-intervention, mid-intervention, post-intervention, and follow-up assessments (2 assessments each). For the intervention phase, the other 3 picture stimuli, "Tea shop," "Beach," and "Kitchen" were used.

Reinforcement such as verbal praise (e.g., “yes, it's correct, good job”), online games and tangible rewards, supported his engagement and motivation across sessions. During the intervention, child initially produced targets only at the word level. With consistent modeling and prompting, he progressed to phrase-level and subsequently sentence-level production by 10 sessions. A multimodal stimulation was used throughout the intervention to correct the misarticulations. The child was found to be motivated to accurately produce each target word embedded with the target sound at the sentence level. By the 4th session, accurate production of /ɖ/ was achieved at the word and phrase levels, and by the 7th session, it was achieved across almost all target words in all positions at the sentence level. Consistent home-based training was carried out by the parent, and regular attendance across all sessions was maintained throughout the intervention period.

4.1.1 Qualitative articulatory outcome measure findings

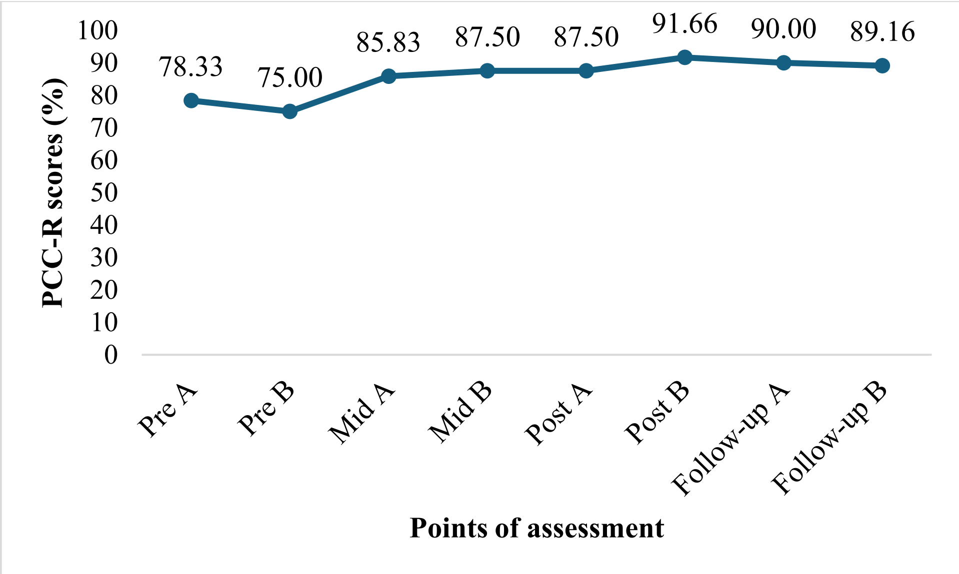
The pre-intervention assessment showed errors across all word positions (initial, medial, and final), with substitutions noted in all positions, distortions in medial and final positions, and omissions in medial positions. During the pre-intervention, PMV analysis revealed errors across all word positions with SODA assessment showing a combination of substitutions ("/d̪/" and /ʈ/ for /ɖ/), distortions, and omissions of /ɖ/. By mid-intervention assessment, the child had eliminated the errors in the initial position with errors reducing to medial and final positions only, and error types simplifying progressively as distortions and omissions reduced. At the post-intervention phase, errors were largely confined to the medial position with substitutions being the primary error type (Post A), with a minor recurrence of errors was observed across medial and final positions at Post B. At follow-up, errors were limited to the final position only, with only one substitution noted and no distortions or omissions present at either follow-up point. These gains in PMV and SODA measures indicate robust treatment effects.

4.1.2 Quantitative articulatory outcome measure findings

Figure 4.1 presents the PCC-R scores across all eight assessment points. At baseline, Pre-intervention A and Pre-intervention B scores were 78.33% and 75.00%, respectively, reflecting consistent consonant production errors. A notable improvement was observed during the mid-assessment phase, with scores improving from approximately 85.83% (Mid-intervention A) and 87.50% (Mid-intervention B), indicating positive early gains following the onset of intervention. Post-intervention scores demonstrated continued improvement, with Post-intervention A PCC-R scores of 87.50% and Post-intervention B PCC-R scores of 91.66%, reflecting substantial enhancement in accurate retroflex production following the completion of the intervention phase. Follow-up PCC-R scores after 1 week was 90.00% (Follow-up A) and 89.16% (Follow-up B) indicating that the therapeutic gains were largely maintained over time, with only minimal variation between the two follow-up points and no clinically significant regression. The overall trajectory reflects a meaningful and consistent improvement in target production accuracy, which is particularly notable given child's background of profound bilateral sensorineural hearing impairment managed with bimodal hearing devices.

Figure 4.1

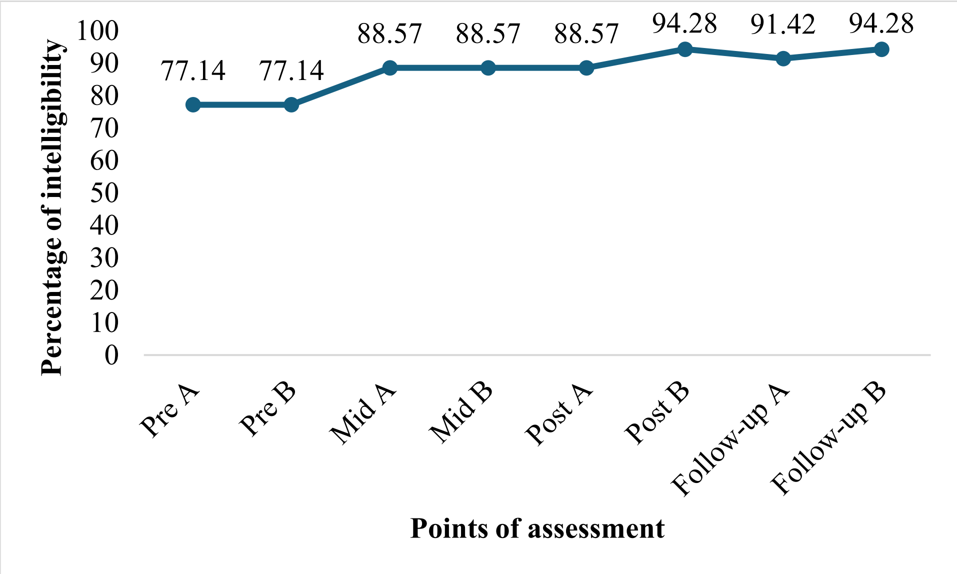
PCC-R scores across pre-intervention (Pre A&B), mid-intervention (Mid A&B), post-intervention (Post A&B) and follow-up (A&B) phases for participant 1



The percentage of speech intelligibility scores during pre-intervention, i.e., both pre-intervention A and B scores were 77.14%, as shown in figure 4.2. A marked improvement observed at the mid-intervention assessments, with both mid-intervention A and B scores increasing from the baseline score of approximately 77.14% to 88.57%, reflecting enhanced speech clarity following the initiation of intervention. Post A intelligibility remained stable at 88.57%, with a further significant improvement observed at Post B, reaching 94.28%, indicating progressive gains through the course of intervention. The follow-up scores of 91.42% (Follow-up A) and 94.28% (Follow-up B) suggest that the progress achieved during the intervention was well maintained with no regression observed, indicating robust and stable treatment outcomes.

Figure 4.2

Percentage of intelligibility scores across pre-intervention (Pre A&B), mid-intervention (Mid A&B), post-intervention (Post A&B) and follow-up (A&B) phases for participant 1



4.2. Participant 2

EFG was a 4-year-old boy with bilateral profound sensorineural hearing impairment, fitted with bimodal hearing (cochlear implant on the left ear implanted at 2.2 years of age and hearing aid on the right ear since 1.6 years of age). Both devices were used consistently in all assessment and intervention phases. Child presented with speech sound errors with a receptive and expressive language age of 2.7-2.9 years in ACSLS. Misarticulations noted in MAT-R were substitutions of /ʈ/ for /ɖ/, /k/ for /ɖ/, /j/ for /ɖ/, /ɳ/ for /ɖ/, /j/ for /r/ across all word positions, Omissions of /ɖ/ in initial and medial position and /r/ in medial position and distortions /ɖ/, /ʈ/ and /r/ especially in multisyllabic words. This phonological error was consistent across all word positions. Speech intelligibility was reduced at the word and phrase level. So, as /ɖ/ production was more substituted (with /ʈ/ and /ɳ/) and omitted, it was taken as the target sound for intervention. The theme selected for EFG for all eight points of assessment was “Bedroom”.

For the intervention phase, three other picture stimuli with the theme “Tea shop,” “Beach,” and “Kitchen” were used.

Reinforcement through tangible rewards such as stickers and friendly competition with the mother to win gifts was particularly effective in maintaining motivation across sessions. Throughout the 10 intervention sessions, the child began to produce the target at the word level. With consistent verbal prompting and phonetic placement, production gradually extended to the phrase level by 5^{th} session, with occasional attempts in producing 2–3 word sentences by 8^{th} session, though progress at the sentence level remained inconsistent. Being the youngest participant in the study at 4 years of age, a highly play-based and multimodal stimulation approach was used to sustain attention and engagement of the child during sessions. By around 5^{th} session, omission errors were eliminated, and by 7-8^{th} session, after the second post-intervention, substitution errors were reduced and /ɖ/ was accurately produced in almost all positions in most of the target words. The child demonstrated gradual and steady progress aided by active parental involvement and regular home training.

4.2.1 Qualitative articulatory outcome measure findings

The repeated pre-intervention assessment revealed misarticulations across all three-word positions initial, medial, and final, with a combination of substitutions (/ʈ/ for /ɖ/, /j/ for /ɖ/, /ɳ/ for /ɖ/, /k/ for /ɖ/) and omission of /ɖ/ characterized his error profile. PMV analysis revealed error in all word positions, with SODA assessment indicating co-occurring substitutions and omissions of /ɖ/. At mid-intervention, errors were present across all three positions in both assessments. However, the error profile began to simplify, with omissions reducing and substitutions becoming the only error type across both mid-intervention assessments. In the post-intervention phase, misarticulations persisted across initial, medial, and final positions in both Post A and B assessments, with substitution (/ʈ/ and /k/ for /ɖ/)

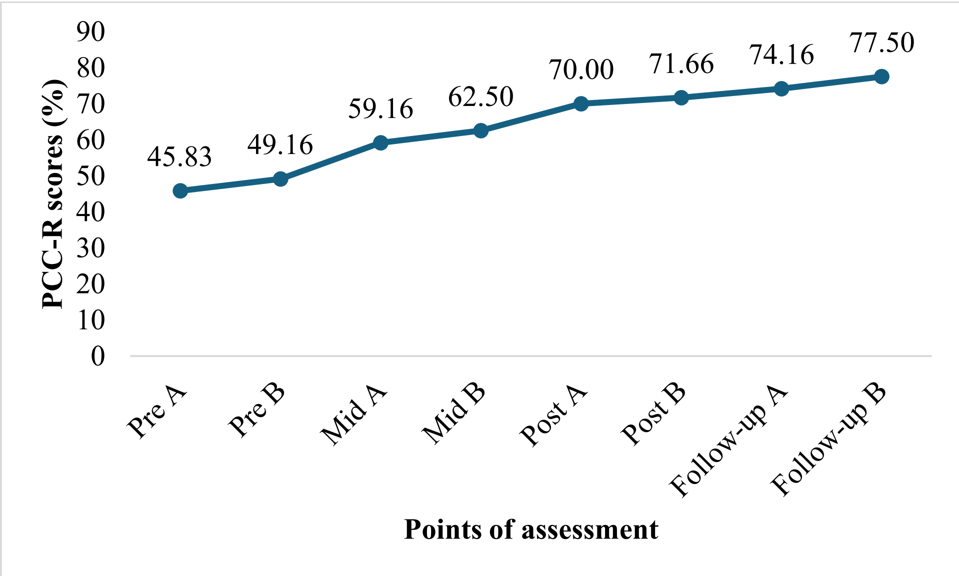
remaining the only error type. A similar pattern was observed at both follow-up points, where errors continued to occur across all word positions but limited to substitutions, with no omissions or distortions observed. These results reflect a qualitative reduction in error severity with persistent positional involvement. Findings from PMV and SODA measures, therefore suggest a partial treatment response, with improvement in error severity and complexity despite continued misarticulations.

4.2.2 Quantitative articulatory outcome measure findings

Figure 4.3 shows the PCC-R scores for Participant 2 across four phases of intervention. Initial baseline assessments showed a PCC-R score of 45.83% in Pre A and a slight increase to 49.16% in Pre B, which were consistent with the child's age and the severity of his presenting speech errors. A steady upward trend was observed through the mid-assessment phase, with scores of 59.16% (Mid A) and 62.50% (Mid B), indicating early responsiveness to intervention. Post-intervention scores continued to improve, reaching 70.00% (Post A) and 71.66% (Post B), reflecting the effectiveness of the intervention in enhancing consonant production accuracy. Follow-up scores of 74.16% (Follow-up A) and 77.50% (Follow-up B) showed continued improvement beyond the structured intervention phase, with no regression observed. Overall, PCC-R scores showed a gradual and consistent increase from the baseline phase (45.83%–49.16%) to the final follow-up phase (77.50%), reflecting notable improvement in speech intelligibility and phonological accuracy. Notably, the progressive increase without any decline suggests a consistent positive response to intervention across the entire study period.

Figure 4.3

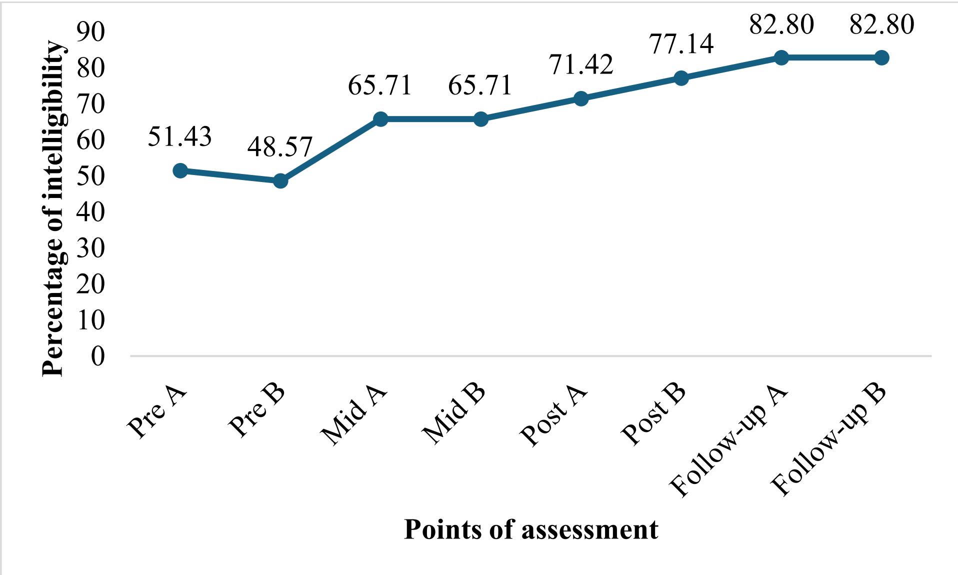
PCC-R scores across pre-intervention (Pre A&B), mid-intervention (Mid A&B), post-intervention (Post A&B) and follow-up (A&B) phases for participant 2



Initial pre intervention intelligibility scores were 51.43% (Pre A) and 48.57% (Pre B) as shown in figure 4.4, indicating considerably reduced speech intelligibility at the initial phase. A slight with decline was noted in Pre B compared to Pre A, indicating some variability in baseline performance. A marked improvement was noted at mid-assessments, with both Mid A and Mid B recordings showing intelligibility scores of 65.71%, reflecting a consistent progress after the initiation of intervention. Post-intervention scores rose further to 71.42% (Post A) and 77.14% (Post B), demonstrating a marked gain between the two post-intervention points, which indicates an active improvement following 10 intervention sessions. Follow-up scores of 82.80% at both Follow-up A and Follow-up B indicated that intelligibility scores increased and was maintained with no regression. This continued improvement from post-intervention to follow-up phase highlights the effectiveness of home training and parental involvement in facilitating the carryover and maintaining the learned productions.

Figure 4.4

Percentage of intelligibility scores across pre-intervention (Pre A&B), mid-intervention (Mid A&B), post-intervention (Post A&B) and follow-up (A&B) phases for participant 2



4.1. Participant 3

LMN is a 6-year-old child with bilateral profound sensorineural hearing impairment, fitted with bimodal hearing (cochlear implant on the right ear implanted at 2.5 years of age and hearing aid on the left ear since 6 months of age). Both devices were used consistently throughout all assessment and intervention sessions. Child exhibited speech sound disorder with receptive language age of 2.10-3.0 years and expressive language age of 2.7-2.9 years in ACSLS. Initial assessment using MAT-R revealed substitutions of /d̪/ for /ɖ/, /k/ for /ɖ/, /ɭ/ for /ɖ/, /v/ for /b/ across all word positions, Omissions of /ɖ/ in medial and final position and distortions of /r/. Cluster reductions were also present. Speech intelligibility at the phrase and sentence level was more compromised with a higher frequency of errors in multisyllabic words. Phoneme /ɖ/ was taken as the target sound for intervention. The theme selected for LMN was

"Bedroom". For the intervention phase, other three pictures with the theme "Tea shop," "Beach," and "Kitchen" were used.

Reinforcement through tangible rewards such as chocolates, stickers, and colouring activities was particularly effective in maintaining engagement and motivation during sessions. Multimodal stimulation and graded cueing were used consistently. By around 7^{th} session, omission errors were completely eliminated with only 5 substitutions noted, primarily involving /t̪/ and /d̪/. By around 10^{th} session, accurate production of /ɖ/ was achieved, reflecting consistent and measurable progress over the course of the intervention. Parental involvement during the early sessions was minimal, yet with targeted counselling, caregivers demonstrated notably improved participation as the intervention progressed.

4.3.1 Qualitative articulatory outcome measure findings

LMN demonstrated partial and variable improvement in speech sound accuracy across the intervention period. At baseline, PMV analysis revealed errors across all word positions, initial, medial, and final, with SODA assessment showing substitutions of /d̪/ for /ɖ/, /k/ for /ɖ/, /ɭ/ for /ɖ/and omission of /ɖ/. Omission errors resolved from Mid A onward, with substitutions remaining as the primary error type throughout the intervention. Initial position errors were resolved at Mid B; however, this was not maintained at Post A and Post B, where errors recurred across all three positions. At follow-up, errors were limited to initial and medial positions at both Follow-up A and Follow-up B, indicating a gradual narrowing of the error range in the later phase. The persistence of errors across multiple positions through the post-intervention phase, together with the variable PCC-R scores, indicates that while the intervention resulted in notable improvement, complete generalization of the target sound was not established within the 10-session period.

4.3.2 Quantitative articulatory outcome measure findings

Figure 4.5 presents the PCC-R scores for Participant 3 across all 8 assessment points. The pre-intervention scores showed notable variability, with Pre A at 45.00% and Pre B rising to 57.50%, indicating some inconsistency in error patterns during baseline. Mid-assessment scores of 68.33% (Mid A) and 66.66% (Mid B) reflected meaningful early gains following the onset of intervention. There was a slight decline between Mid A and Mid B, suggesting some performance variability. Post-intervention scores of 65.83% (Post A) and 68.33% (Post B) were broadly consistent with mid-intervention scores, indicating a plateau rather than further growth during the post-intervention phase. Follow-up scores of 70.83% (Follow-up A) and 68.33% (Follow-up B) showed limited improvement after the intervention, with a slight decline at Follow-up B, suggesting some inconsistency in maintenance. Overall, while gains from pre-intervention to follow-up were evident, the fluctuating trajectory indicates variable consolidation of the target sound across the assessment period.

Figure 4.5

PCC-R scores across pre-intervention (Pre A&B), mid-intervention (Mid A&B), post-intervention (Post A&B) and follow-up (A&B) phases for participant 3

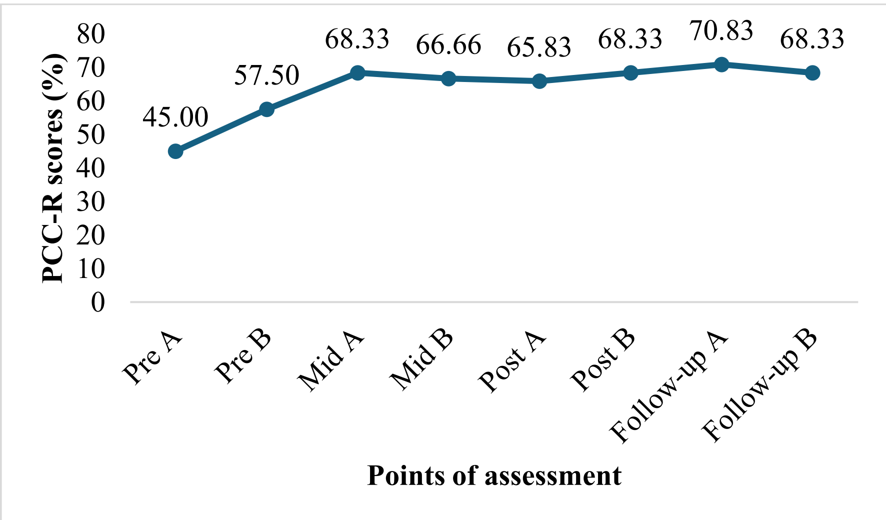
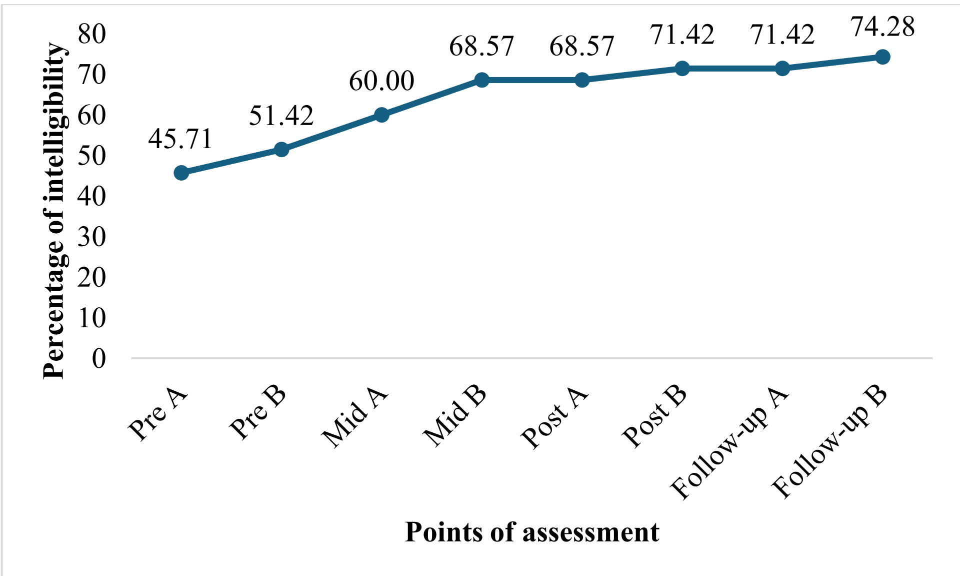


Figure 4.6 illustrates the percentage of intelligibility scores for Participant 3 across four intervention phases. Baseline scores were 45.71% (Pre A) and 51.42% (Pre B), indicating markedly reduced speech intelligibility at the outset. Progressive improvement was observed through the mid-assessment phase, with Mid A at 60.00% and Mid B at 68.57%, reflecting enhanced speech clarity following the initiation of intervention. Post A and Post B scores remained almost stable at 68.57% and 71.42%, respectively, indicating a plateau without further marked increase. Follow-up scores of 71.42% (Follow-up A) and 74.28% (Follow-up B) demonstrated sustained maintenance of the gains, with a fair additional improvement at Follow-up B. Although the overall improvement from baseline to follow-up is clinically significant, the plateau observed from mid-intervention assessment onwards suggests that further intervention may be required to achieve higher levels of intelligibility.

Figure 4.6

Percentage of intelligibility scores across pre-intervention (Pre A&B), mid-intervention (Mid A&B), post-intervention (Post A&B) and follow-up (A&B) phases for participant 3



4.1. Participant 4

XYZ was a 5-year-old child diagnosed with profound bilateral sensorineural hearing impairment, fitted with bimodal hearing (cochlear implant on the right ear at 3 years of age and hearing aid on the left ear since 1.8 years of age). Both amplification devices were worn consistently during all assessment and intervention sessions. Child had speech sound errors, presenting with a receptive and expressive language age of 2.7-2.9 years in ACSLS. His speech was marked by substitutions of /d̪/ for /ɖ/, /t̪/ for /ɖ/ in MAT-R. There were inconsistent substitutions for phoneme /k/ and the omission of /k/ and /ɖ/. This phonological error was consistent across all word positions including initial, medial, and final. Along with substitutions, child also exhibited incorrect productions of other speech sounds, particularly retroflex sounds such as /r/. Speech intelligibility was reduced at the phrase level. Finally, the speech sound /ɖ/ was taken as the target for intervention. The picture stimulus selected for pre-intervention, mid-intervention, post-intervention, and follow-up assessments was "Bedroom". For the intervention phase, three other picture stimuli "Tea shop," "Beach," and "Kitchen" were selected.

Child required consistent multimodal stimulation with cueing across sessions to approximate the target sound. Reinforcement was provided through online games and tangible rewards. Although omission errors were resolved during the mid-assessment phase, they reappeared at Post A before fully resolving from Post B onwards, reflecting some inconsistency in the stabilization of productions. Accurate production of /ɖ/ was largely achieved after 4–5 sessions, with only occasional substitutions by dental /d̪/ and /t̪/, along with a few omission errors persisting thereafter. Parental involvement and home training were maintained throughout the study, which appeared to contribute to the continued improvement in intelligibility scores observed even at follow-up.

4.4.1 Qualitative articulatory outcome measure findings

XYZ demonstrated gradual but meaningful improvement in speech sound accuracy throughout the intervention. At pre-intervention, PMV analysis revealed errors across all word positions, initial, medial, and final, with SODA assessment showing substitutions /d̪/ for /ɖ/, /t̪/ for /ɖ/ and omission of /ɖ/. Omission errors were reduced at Mid A and Mid B, but recurred again at Post A before fully resolving from Post B onward, highlighting some instability in the consolidation of error-free productions during the immediate post-intervention phase. Errors across all three positions (initial, medial, and final) persisted through Follow-up A, with a notable reduction to only medial and final positions at Follow-up B, indicating a partial narrowing of the error range in the latter follow-up phase. Substitutions remained the primary error type throughout, with no new error types emerging.

4.4.2 Quantitative articulatory outcome measure findings

Figure 4.7 presents the PCC-R scores for Participant 4 during the pre-intervention, mid-intervention, post-intervention, and follow-up phases. The pre-intervention scores of 35.83% (Pre A) and 41.66% (Pre B) indicated the most severe level of consonant production errors among all participants at baseline. A gradual upward trend was observed through the mid-assessment phase, with scores of 48.33% (Mid A) and 49.16% (Mid B) reflecting early but steady improvement. Post-intervention scores of 49.16% (Post A) and 52.50% (Post B) showed continued improvement, suggesting a slow pace of consolidation during the immediate post-intervention period. The most notable change was observed at follow-up, with scores of 60.00% (Follow-up A) and 61.66% (Follow-up B), indicating that progress continued to persist even after the structured sessions had ended. This continued improvement observed during the follow-up assessments, despite a slower rate of progress during the intervention, may indicate delayed but sustained generalization of the target sound facilitated by home training and active parental involvement.

Figure 4.7

PCC-R scores across pre-intervention (Pre A&B), mid-intervention (Mid A&B), post-intervention (Post A&B) and follow-up (A&B) phases for participant 4

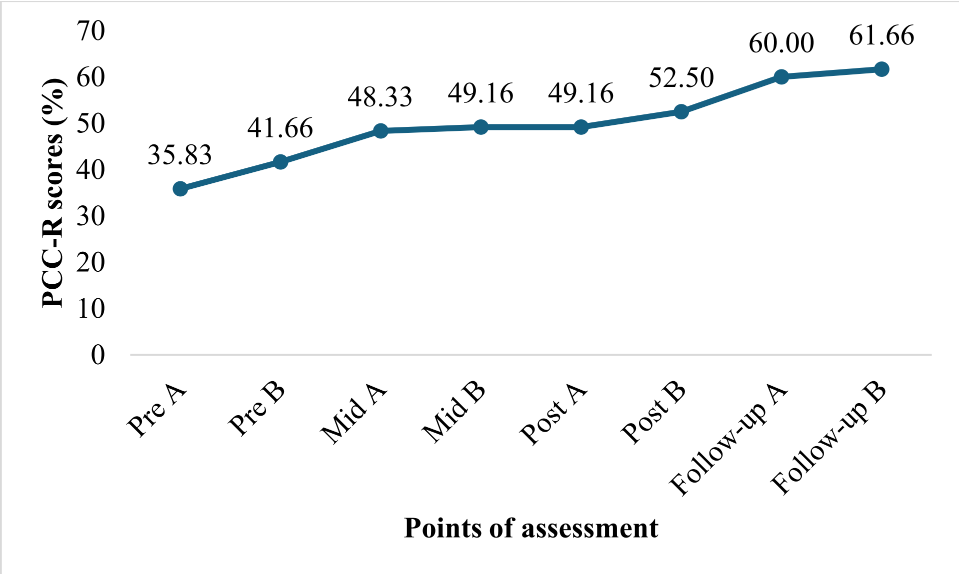
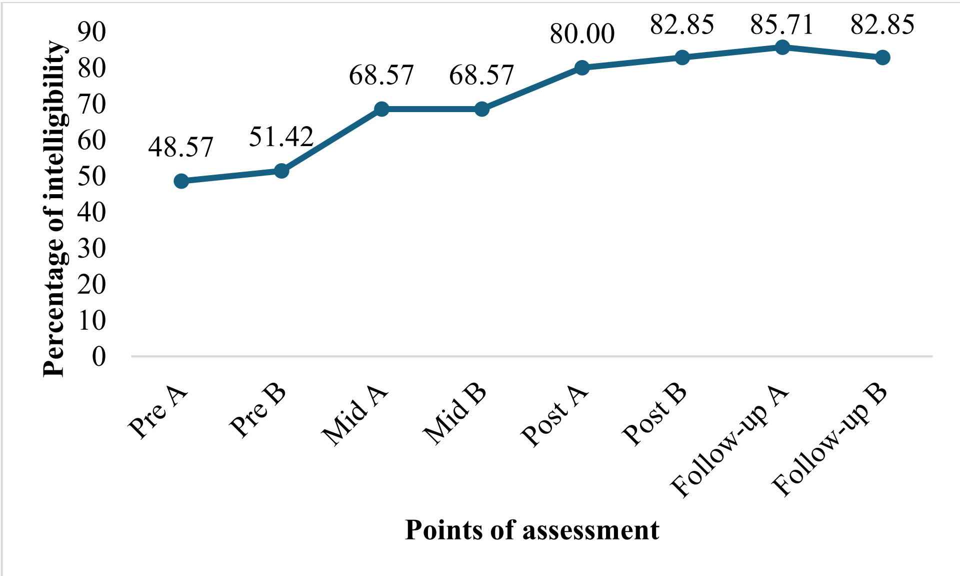


Figure 4.8 illustrates the percentage of intelligibility scores for Participant 4 across all assessments. Baseline scores were 48.57% (Pre A) and 51.42% (Pre B), indicating markedly reduced speech intelligibility at the onset. A substantial improvement was observed at mid-assessment, with both Mid A and B recorded 68.57%, representing a gain of approximately 17 to 20 percentage points from baseline and suggesting a strong early response to the intervention in overall speech clarity. Post-intervention scores showed a further significant improvement, reaching 80.00% (Post A) and 82.85% (Post B), indicating that gains in intelligibility exceeded improvements in PCC-R during this phase, potentially reflecting broader improvements in connected speech beyond the target sound alone. Follow-up scores of 85.71% (Follow-up A) and 82.85% (Follow-up B) confirmed sustained maintenance of these gains, with only slight

variation between the two follow-up points and no regression observed, demonstrating stable treatment outcomes.

Figure 4.8

Percentage of intelligibility scores across pre-intervention (Pre A&B), mid-intervention (Mid A&B), post-intervention (Post A&B) and follow-up (A&B) phases for participant 4



4.1. Participant 5

OPQ was a 9-year-old child diagnosed with profound bilateral sensorineural hearing impairment, fitted with bimodal hearing (cochlear implant on the right ear at 4 years of age and hearing aid on the left ear since 2 years of age). Both devices were used consistently throughout all assessment and intervention phases. During the study enrolment, child presented with speech sound errors, with a receptive language age of 5.6–6.0 years and expressive language age of 3.0–3.6 years as measured by the ACSLS. Initial assessment using the MAT-R revealed substitutions of /t̪/ for /ʈ/, /ɖ/ for /ʈ/, /p/ for /m/ across all word positions, with distortions of /r/, /ɭ/ and /ʈ/ co-occurring alongside substitutions at baseline. Speech intelligibility was reduced at the sentence level. Thus, retroflex voiceless stop /ʈ/ was selected for intervention for OPQ. The picture stimulus “Tution centre” was selected for pre-intervention, mid-intervention, post-intervention, and follow-up assessments. For the intervention phase, the picture theme “Hotel,” “Garden,” and “Utility room” were used.

Reinforcement such as verbal praise (e.g., “yes, that’s correct”), interactive online games and tangible rewards, helped maintain the child’s engagement and motivation across the sessions. Child was found to be stimulable and by the 7th session, near accurate production of /ɖ/ was established at the word and phrase levels, and by the 10th session, it was generalized across all target words in all positions at the sentence level. Regular attendance across all sessions was maintained throughout the intervention period; however, variability in home training consistency was observed, with parent-guided practice being irregular during certain sessions.

4.5.1 Qualitative articulatory outcome measure findings

Among the participants presenting with substitution and distortion errors, OPQ demonstrated a complex error pattern that persisted across multiple assessment phases. Multimodal stimulation was used consistently throughout the sessions for correcting the misarticulations. Initial assessment revealed errors at all positions in PMV analysis, with SODA assessment showing a combination of consistent substitutions of /t̪/ for /ʈ/ and /ɖ/ for /ʈ/, and distortion of /ʈ/. Final position errors resolved from Mid-intervention B, with errors reducing to initial and medial positions, and this improvement in error pattern was maintained consistently through all subsequent assessment points, including both follow-up assessments. With regard to error type, substitution and distortion errors co-occurred across most assessment phases; however, Post B showed only distortion errors, but substitutions recurred at Follow-up A. Notably, at Follow-up B, distortions alone were observed as the remaining error type, suggesting a positive shift toward improved articulatory precision even in the absence of complete error resolution. This shift from predominantly substitution errors at pre-intervention to distortion-only errors at the final follow-up assessment indicates a meaningful qualitative change in the nature of the error pattern, indicating closer approximation towards the target sound even if full accuracy was not achieved within the intervention period.

4.5.2 Quantitative articulatory outcome measure findings

Figure 4.9 depicts the PCC-R scores for Participant 5 across all eight time points. At baseline, Pre A recorded 72.22%, while Pre B showed a decline to 67.50%, indicating some variability in baseline error consistency. Mid A scores returned to 72.22%, with a more notable improvement at Mid B reaching 78.70%, reflecting progressive improvements through the mid-intervention phase. Post A scores reached 83.33%, representing the highest PCC-R score across all assessment points for this participant; however, a decline to 78.70% was observed at Post B, suggesting some instability in productions immediately following intervention completion. Follow-up scores of 81.48% (Follow-up A) and 80.55% (Follow-up B) reflected partial maintenance of the post-intervention gains, with a slight decline from the Post A peak but without complete regression. OPQ exhibited excellent response to intervention with near resolution of all documented errors.

Figure 4.9

PCC-R scores across pre-intervention (Pre A&B), mid-intervention (Mid A&B), post-intervention (Post A&B) and follow-up (A&B) phases for participant 5

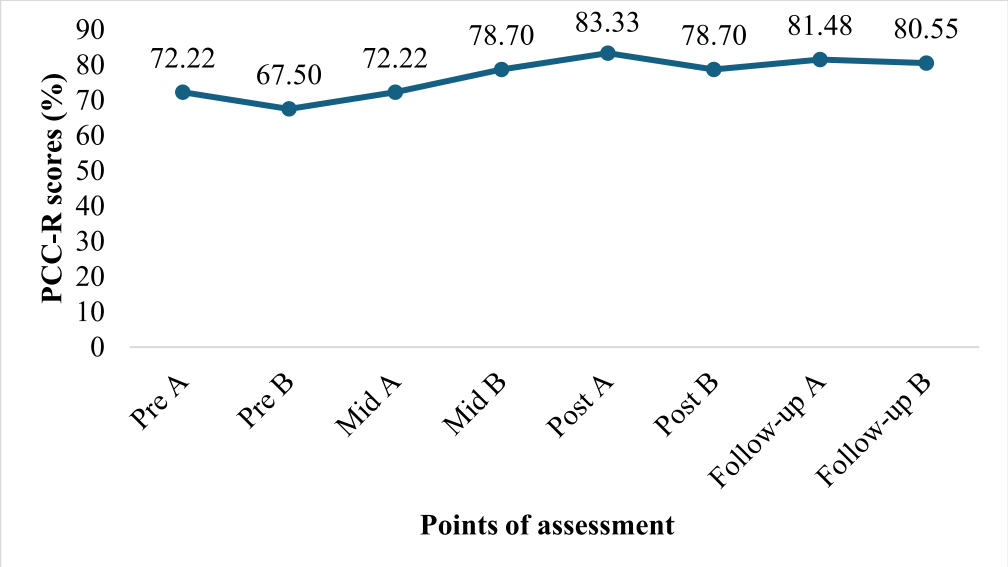
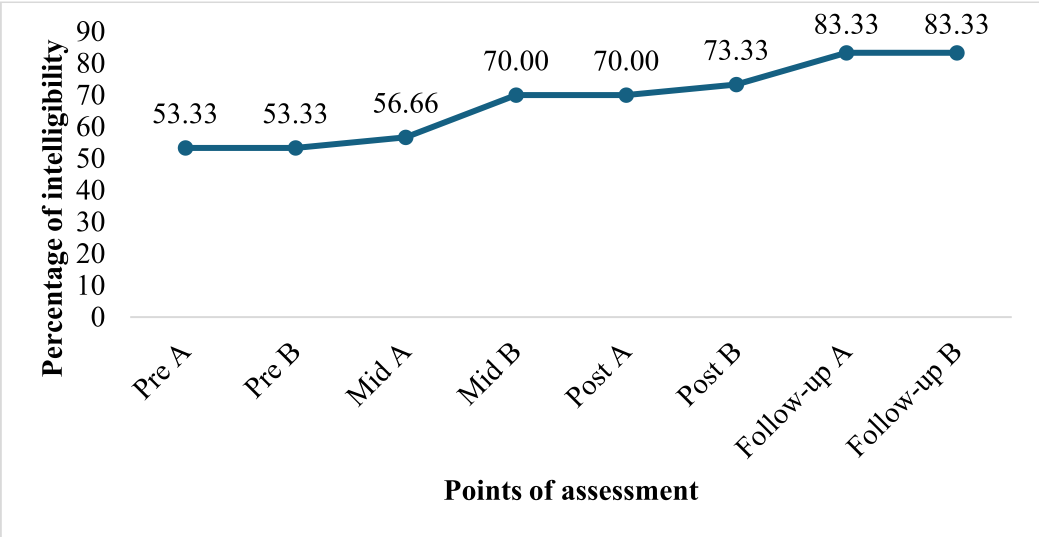


Figure 4.10 illustrates the progression of speech intelligibility in Participant 4 across three phases of the intervention. Baseline scores were 53.33% at both Pre A and Pre B, indicating considerably reduced speech intelligibility, consistent with the presence of both substitution and distortion errors at baseline. A modest improvement was observed at Mid A with 56.66%, followed by a more substantial gain at Mid B reaching 70.00%, reflecting good improvement through the latter mid-intervention phase. Post A scores remained stable at 70.00%, with a further improvement at Post B reaching 73.33%, indicating consolidation of intelligibility gains through the post-intervention phase. The most marked improvement was observed at follow-up, with scores of 83.33% at both Follow-up A and Follow-up B, representing a gain of approximately 10 percentage points from post-intervention and demonstrating continued improvement beyond the structured intervention period. The identical and sustained scores at both follow-up assessments suggest stable maintenance of the intelligibility gains, even though PCC-R scores continued to show variability at the same time points.

Figure 4.10

Percentage of intelligibility scores across pre intervention (Pre A&B), mid-intervention (Mid A&B), post-intervention (Post A&B) and follow-up (A&B) phases for participant 5



4.6 Reliability

4.6.1 Inter-judge reliability

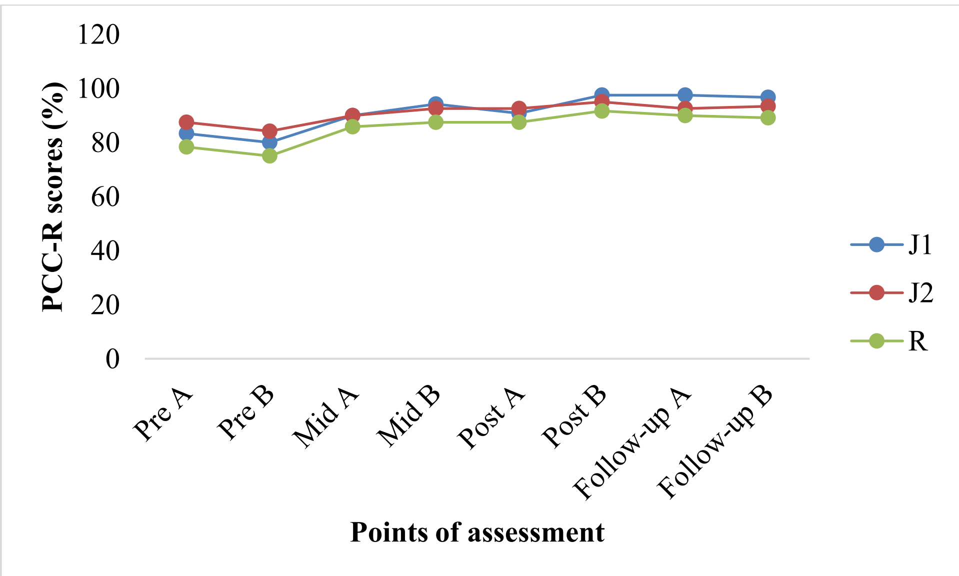
To establish inter-judge reliability, two experienced speech-language pathologists (SLPs) who were not acquainted with the participants, independently scored the speech samples across all assessment stages. 20% of the data were re-analyzed the two other judges. Reliability was evaluated for PCC-R, PI, PMV, and SODA measures across pre-intervention, mid-intervention, post-intervention, and follow-up phases. Since this is a single-subject study, statistical reliability indices were not computed.

For the qualitative measures, PMV and SODA, both areas of agreement and some discrepancies were noted. At Pre A and Pre B, all three judges agreed on positional involvement, with errors noted across initial, medial, and final positions. SODA agreement was strong at Pre B, with all three judges identifying co-occurring substitutions, omissions, and distortions. In Pre A, a minor difference was noted; judge 1 recorded substitution only, while others also noted distortion. At Mid A and Mid B, small variations emerged in both positional and SODA judgements, mainly around whether omission or distortion errors were present. At Post A and Post B, positional disagreements were minor, with SODA differences limited to whether distortion or omission was recorded along with substitution. The most notable discrepancies emerged at the follow-up stage, where judge 1 recorded no errors at either Follow-up A or B, while judges 2 and the researcher identified residual substitution and omission errors at medial and final positions.

For PCC-R, scores provided by the judges were largely consistent across all stages, with both judges and the researcher presenting an upward trend from pre-intervention through follow-up, as shown in Figure 4.11. Judge 1 scores ranged from 83.33% (Pre A) to 96.66% (Follow-up A), judge 2 scored 87.50% to 93.33%, and the researcher's scores ranged from 78.33% to 89.16%, reflecting a systematic but consistent difference in scoring stringency.

Figure 4.11

Inter-judge reliability PCC-R scores across pre-intervention (Pre A&B), mid-intervention (Mid A&B), post-intervention (Post A&B) and follow-up (A&B) phases

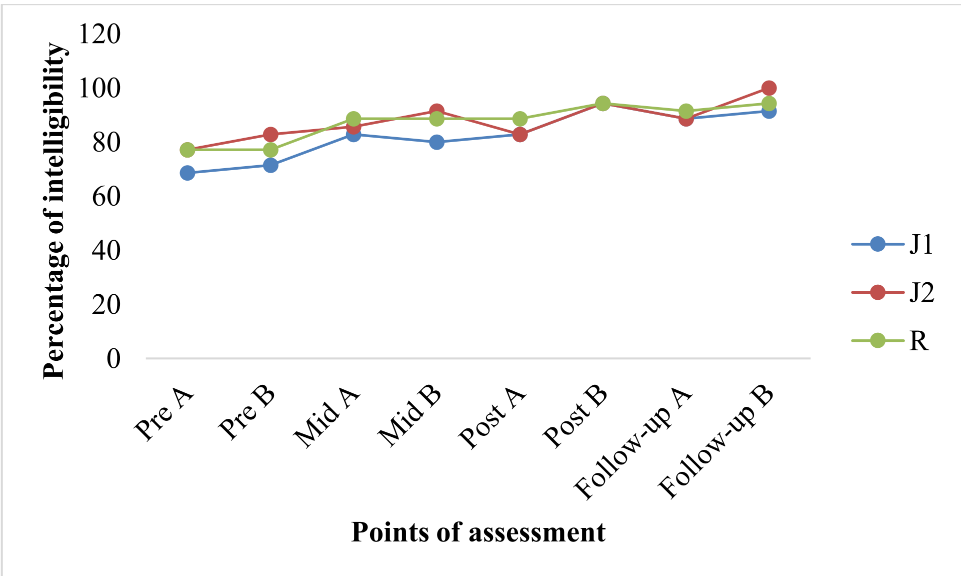


Note. J1= Judge 1, J2 = Judge 2, R = Researcher

A similar pattern was observed for percentage of intelligibility, with all three scorers showing progressive improvement across phases as shown in Figure 4.12. Judge 1 scored 68.57% in Pre A to 91.42% in follow-up B, judge 2 scores ranged from 77.14% to 100.00 indicating no errors with good intelligibility. Primary researcher scored from 77.14% (Pre A) to 94.28% (Follow-up B). Some scores converged closely at some assessment points; in particular, the two judges and the researcher provided identical scores at Post (94.28%). At Pre A, judge 1 and the researcher scored as 77.14% and at Follow-up A, both judges scored 88.57%, indicating greater scoring agreement as productions became more consistent.

Figure 4.12

Inter-judge reliability percentage of intelligibility scores across pre-intervention (Pre A&B), mid-intervention (Mid A&B), post-intervention (Post A&B) and follow-up (A&B) phases



Note. J1= Judge 1, J2 = Judge 2, R = Researcher

The variables noted in the reliability judgment included the elicitation of target sound at the word level in pre-intervention phase, and by the end of intervention, the post-intervention recordings captured sentence level productions. The intelligibility of the client at word level is reported to be good than sentence level because distortions were observed to be more prominent at the sentence level, with intelligibility improving progressively with correction cues. Judge 1 reported that the audio clarity was reduced for few number of words, which may have contributed to scoring differences.

4.6.2 Intra-judge reliability

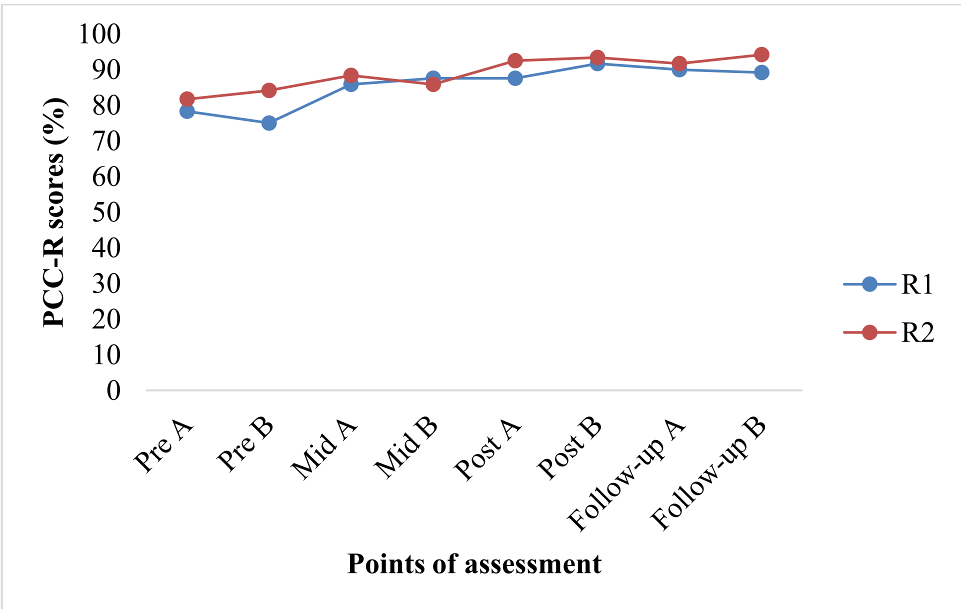
Intra-judge reliability was assessed by having the primary researcher re-analyze a 20% of the data after a two-week interval, without access to the original scores during re-scoring. This is to examine the consistency of the researcher's own judgements over time.

SODA and PMV analysis were largely in agreement between the two scoring instances, with minor discrepancies observed at pre-intervention and follow-up stages. Complete agreement was observed at Pre A and Pre B, with substitutions and distortions identified across all positions. At Mid A, substitutions and distortions were noted, while at Mid B, substitutions and omissions were noted, both in medial and final positions. At Post A, a minor discrepancy was observed, with scoring 1 identifying medial position substitution only, while scoring 2 recorded substitution and distortion at medial and final positions. Both scorings agreed at Post B on medial and final position errors for PMV and substitution and omission for SODA. At Follow-A, scoring 1 noted substitution, while scoring 2 additionally identified distortion at final position. At Follow-up B, scoring 1 recorded final position substitution, while scoring 2 revealed no errors on either measure. These slight inconsistencies reflect the perceptual challenge of categorizing subtle, infrequent errors, particularly at the sentence level. Overall, the intra-judge reliability findings were satisfactory across the two-week interval.

In Figure 4.13, PCC-R was quantitatively calculated, and the two scoring instances showed close agreement across all stages, with scoring 1 ranging from 78.33% (Pre A) to 89.16% (Follow-up B) and scoring 2 ranging from 81.66% (Pre A) to 94.16% (Follow-up B). Figure 4.14 represents the percentage of intelligibility, where scoring 1 ranged from 77.14% (Pre A) to 94.28% (Follow-up B) and scoring 2 ranged from 65.71% (Pre A) to 94.28% (Follow-up B). A notable difference was observed at Pre A, likely reflecting variability in scoring target sounds during the early baseline phase. Across mid-intervention and later assessments, the two scoring instances converged closely, indicating stable and consistent judgment.

Figure 4.13

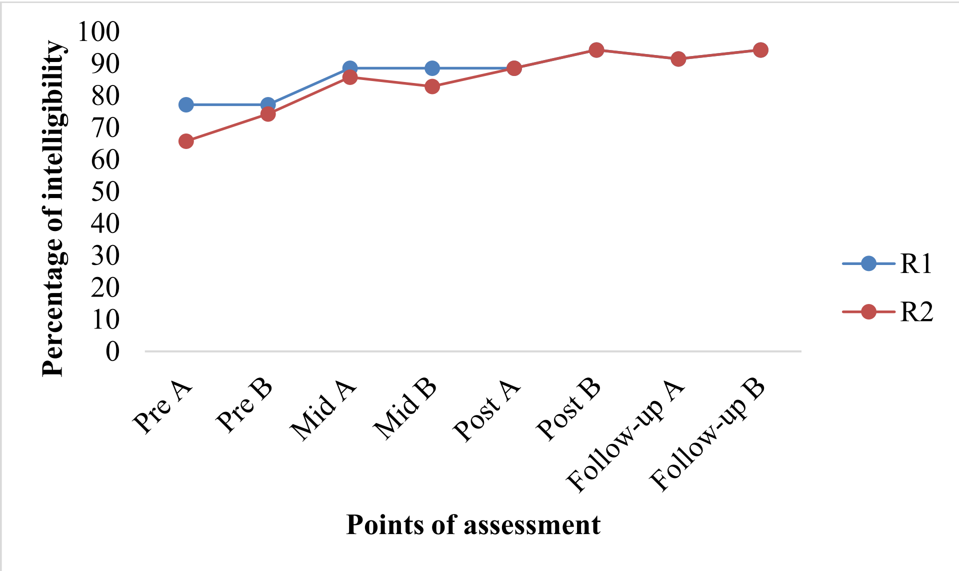
Intra-judge reliability PCC-R scores across pre-intervention (Pre A&B), mid-intervention (Mid A&B), post-intervention (Post A&B) and follow-up (A&B) phases



Note. R1= Rating 1 by researcher, R2 = Rating 2 by researcher

Figure 4.14

Intra-judge reliability percentage of intelligibility scores across pre-intervention (Pre A&B), mid-intervention (Mid A&B), post-intervention (Post A&B) and follow-up (A&B) phases



Note. R1= Rating 1 by researcher, R2 = Rating 2 by researcher

4.7 Factors influencing articulation outcomes across participants using qualitative analysis

Across the five participants, there appeared several distinct patterns relating to terms of error type, responsiveness to intervention, and retention of therapeutic effects. Cross-case analysis revealed that the outcomes after the intervention were determined not only by any single factor but rather by interactions between multiple variables, including error type and severity, stimulability, parental involvement, and language age.

The type of error at pre-intervention played a significant role in shaping further intervention. All five subjects presented with substitution errors as their major error type; however, Participants 1 and 5 were additionally characterized by distortions reflecting greater articulatory complexity. Participant 1, despite exhibiting substitutions, distortions, and omissions across all positions at baseline, demonstrated significant improvement across all measures and achieved accurate production at the sentence level by 7th session. In contrast, Participant 5 whose errors included substitutions and distortions, showed a shift to distortion only errors by follow-up; however, completely accurate production was not achieved within the 10-session period. This is consistent with the evidence from ASHA National Outcome Measurement System (ASHA NOMS; 2005-2009), which suggests that 17 to 20 treatment hours are required for sufficient intervention on a single sound when error patterns are complex.

Stimulability emerged as a critical factor among participants. Participants 1 and 4 demonstrated good stimulability and achieved accurate or near-accurate productions within 4-7 sessions, with generalization to sentence-level during the intervention period, whereas Participant 2 required a highly play-based and multimodal approach to sustain engagement. Another important factor is the parental involvement and consistency of home training provided. For Participants 1 and 2, active parental involvement was reflected in progressive improvement that continued even into the follow-up phase. Participant 4, although demonstrating a slower pace of progress during intervention sessions, exhibited a marked gain at follow-up, suggesting that sustained home training beyond clinical sessions contributed to stable generalization. In contrast, Participant 3 had minimal parental involvement in the early sessions, reflected greater variability and a plateau in improvement from the mid-intervention phase.

Age alone did not emerge as a determinative factor in outcomes. Participant 1, aged 9 years, and Participant 5, also aged 9 years, showed different outcomes, with Participant 1 achieving accurate production and Participant 5 showing partial improvement. Similarly, Participants 4 (5 years) and 3 (6 years) demonstrated comparable PCC-R ranges at follow-up, suggesting that chronological age, along with other factors such as language age, error severity, and stimulability, contribute to predicting outcomes. Notably, with respect to language age, those with relatively higher language ages at enrolment, such as Participants 1 and 5, did not consistently show superior outcomes, supporting the view that language age alone is insufficient as a prognostic indicator.

In addition, word frequency also seemed to influence production accuracy. In general, it was found that high frequency simple words yield more consistent productions compared to low-frequency words. This observation is consistent with research findings of Geirut (2002), which shows that high-frequency words result in greater generalization in intervention. Thus, the progress made by the participants as a whole is the combined influence of error type and baseline severity, parental engagement, consistency of home training, stimulability, and the language age.

4.8 Statistical analysis

The following statistical analysis was performed:

➢ Descriptive statistics were carried out to determine the median and interquartile ranges.
The Percentage of Consonants Correct (PCC-R) scores and Percentage of intelligibility scores were calculated by considering all target word production.

➢ Friedman test was applied to examine the improvement in treatment over time (pre-post-mid-follow-up)

Table 4.2

Descriptive statistics (Mean, Median, SD, IQR) of PCC-R scores across pre intervention, mid intervention, post intervention and follow-up phases (N=5).

Assessment Point	Mean (%)	Median (%)	SD	IQR
Pre-intervention A	55.44	45.83	18.65	34.86
Pre-intervention B	58.16	57.50	13.46	25.84
Mid-intervention A	66.77	68.33	14.08	25.28
Mid-intervention B	68.90	66.66	14.81	27.27
Post-intervention A	71.16	70.00	15.24	27.92
Post-intervention B	72.57	71.66	14.35	24.77
Follow-up A	75.29	74.16	11.29	20.33
Follow-up B	75.44	77.50	10.71	19.86

Note. PCC-R = Percentage of Consonants Correct- Revised

Table 4.2 presents the descriptive statistics for PCC-R scores across all eight assessment points. Mean PCC-R scores increased from 55.44% (SD = 18.65) at Pre A to 75.44% (SD = 10.71) at Follow-up B, reflecting a consistent improvement in consonant accuracy over the intervention period. Median scores also followed a similar pattern, rising from 45.83 at Pre A to 77.50at Follow-up B. The standard deviation decreased from 18.65 at Pre A to 10.71 at Follow-up B, indicating that individual variability in consonant production reduced as participants progressed through the intervention. The interquartile range also narrowed from 34.86 at Pre A to 19.86 at Follow-up B, further showing more consistent and accurate retroflex stop production across the participants.

Table 4.3

Post-hoc pairwise comparisons for PCC-R scores

Comparison	**Z-value**	**p-value**	**Adj. p-value**
Pre A – Pre B	-0.06	.949	.949
Pre A – Mid A	-1.29	.197	.324
Pre A – Mid B	-1.81	.071	.165
Pre A – Post A	-2.26	.024	.084
Pre A – Post B	-2.97	.003	**.017**
Pre A – Follow-up A	-3.68	< .001	**.007**
Pre A – Follow-up B	-3.42	.001	**.006**
Pre B – Mid A	-1.23	.220	.342
Pre B – Mid B	-1.74	.081	.175
Pre B – Post A	-2.20	.028	.088
Pre B – Post B	-2.91	.004	**.017**
Pre B – Follow-up A	-3.62	< .001	**.004**
Pre B – Follow-up B	-3.36	.001	**.006**
Mid A – Mid B	-0.52	.606	.707
Mid A – Post A	-0.97	.333	.444
Mid A – Post B	-1.68	.093	.187
Mid A – Follow-up A	-2.39	.017	.068
Mid A – Follow-up B	-2.13	.033	.093

Mid B – Post A	-0.45	.651	.730
Mid B – Post B	-1.16	.245	.361
Mid B – Follow-up A	-1.87	.061	.156
Mid B – Follow-up B	-1.61	.107	.199
Post A – Post B	-0.71	.478	.608
Post A – Follow-up A	-1.42	.156	.272
Post A – Follow-up B	-1.16	.245	.343
Post B – Follow-up A	-0.71	.478	.582
Post B – Follow-up B	-0.45	.651	.701
Follow-up A – Follow-up B	0.26	.796	.826

Note. Significance values have been adjusted using the Benjamini–Hochberg False Discovery Rate (FDR) correction. Bold values indicate statistically significant comparisons (Adj. $p < .05$).

Table 4.3 presents the results of post hoc pairwise comparisons for PCC-R scores across eight assessment points, with p-values adjusted using the FDR correlation. The comparisons between pre-intervention assessments and later phases produced statistically significant results. Specifically, Pre A differed significantly from Post B (Adj. $p = .017$), Follow-up A (Adj. $p = .007$), and Follow-up B (Adj. $p = 0.006$). Similarly, Pre B differed significantly from Post B (Adj. $p = .017$), Follow-up A (Adj. $p = .004$), and Follow-up B (Adj. $p = .006$). No statistically significant differences were observed between other assessment points such as pre to mid intervention, mid to post intervention, or post to follow-up after FDR correction. This reflects that while improvement was consistent across phases, the gains gradually accumulated at any single transition point. The significant differences emerging between the baseline and Post B and follow-up phases highlight the sustained nature of the intervention on consonant accuracy.

Table 4.4

Descriptive statistics (Mean, Median, SD, IQR) of percentage of intelligibility scores across pre-intervention, mid-intervention, post-intervention, and follow-up phases (N=5).

Assessment Point	Mean (%)	Median (%)	SD	IQR
Pre-intervention A	55.24	51.43	12.58	18.10
Pre-intervention B	56.38	51.42	11.73	15.24
Mid-intervention A	67.90	65.71	12.46	20.24
Mid-intervention B	72.28	68.57	9.24	12.15
Post-intervention A	75.71	71.42	8.45	15.00
Post-intervention B	79.80	77.14	9.19	16.19
Follow-up A	82.94	83.33	7.29	11.45
Follow-up B	83.51	82.85	7.11	10.27

Note. PCC-R = Percentage of Consonants Correct – Revised.

Descriptive statistics for the percentage of intelligibility scores across the assessment periods are presented in Table 4.4. Mean percentage of intelligibility scores increased progressively from Pre A 55.24% (SD = 12.58) to follow-up B 83.51% (SD = 7.11), indicating consistent improvement in overall speech intelligibility throughout the study period. Median scores similarly increased from 51.43 at Pre A to 82.85 at follow-up B. The standard deviation showed a notable reduction from 12.58 at Pre A to 7.11 at follow-up B, and the interquartile range narrowed from 18.10 to 10.27, both suggesting that as the intervention progressed, the participant variability in intelligibility decreased. The most marked mean improvement occurred between Pre A and Mid B (55.24% to 72.28%), indicating strong early responsiveness to intervention in terms of overall speech clarity. The reduced variability at follow-up suggests that intelligibility gains were maintained beyond the intervention sessions.

Table 4.5

Post-hoc pairwise comparisons for percentage of intelligibility scores

Comparison	Z-value	p-value	Adj. p-value
Pre A – Pre B	-0.13	.897	.897
Pre A – Mid A	-1.29	.197	.290
Pre A – Mid B	-1.68	.093	.174
Pre A – Post A	-2.07	.039	.109
Pre A – Post B	-3.29	.001	**.006**
Pre A – Follow-up A	-3.68	< .001	**.002**
Pre A – Follow-up B	-3.87	< .001	**.003**
Pre B – Mid A	-1.16	.245	.327
Pre B – Mid B	-1.55	.121	.189
Pre B – Post A	-1.94	.053	.114
Pre B – Post B	-3.16	.002	**.007**
Pre B – Follow-up A	-3.55	< .001	**.003**
Pre B – Follow-up B	-3.74	< .001	**.003**
Mid A – Mid B	-0.39	.699	.815
Mid A – Post A	-0.78	.439	.558
Mid A – Post B	-2.00	.045	.116

Mid A – Follow-up A	-2.39	.017	.059
Mid A – Follow-up B	-2.58	.010	**.039**
Mid B – Post A	-0.39	.699	.782
Mid B – Post B	-1.61	.107	.187
Mid B – Follow-up A	-2.00	.045	.106
Mid B – Follow-up B	-2.20	.028	.088
Post A – Post B	-1.23	.220	.308
Post A – Follow-up A	-1.61	.107	.176
Post A – Follow-up B	-1.81	.071	.141
Post B – Follow-up A	-0.39	.699	.752
Post B – Follow-up B	-0.58	.561	.683
Follow-up A – Follow-up B	-0.19	.846	.878

Note. Significance values have been adjusted using the Benjamini–Hochberg False Discovery Rate (FDR) correction. Bold values indicate statistically significant comparisons (Adj. $p < .05$).

Table 4.5 presents the post hoc pairwise comparisons for PI scores across eight assessment points, with p-values adjusted using the FDR correlation. Significant differences were observed between baseline and later intervention and follow-up phases. Pre A differed significantly from Post B (Adj. $p = .006$), Follow-up A (Adj. $p = .002$), and Follow-up B (Adj. $p = .003$). Pre B similarly differed significantly from Post B (Adj. $p = .007$), Follow-up A (Adj. $p = .003$), and Follow-up B (Adj. $p = .003$). Additionally, Mid A differed significantly from follow-up B (Adj. $p = .039$), indicating that intelligibility improvements extended to mid-intervention versus follow-up contrasts as well. No significant differences were found between adjacent phases after FDR correction. Notably, unlike PCC-R comparisons, intelligibility showed significant differences between baseline and Post B, suggesting that intelligibility improvements became statistically more reliable than PCC-R gains. The absence of significant differences between post-intervention and follow-up assessments confirms that intelligibility gains achieved during the intervention were well maintained at follow-up, reflecting stable treatment outcomes.

Overall, the findings confirmed that both PCC-R and percentage of intelligibility scores changed significantly among children with speech sound errors across the eight assessment points. The pairwise comparisons identified that PCC-R gains were statistically reliable between the pre-intervention and Post B through the follow-up phases, while intelligibility improvements were significant from baseline to Post B and follow-up phases, with an additional significant contrast between Mid A and follow-up B. The absence of significant differences between adjacent assessment phases reflects the gradual and cumulative nature of improvement consistent with the single-subject ABA design. These results highlight the clinical efficacy of using retroflex stop-loaded picture stimuli for description during intervention in improving both consonant production accuracy and speech intelligibility in Malayalam-speaking children with hearing impairment using cochlear implants.

Thus, the present study aimed to develop a retroflex stop loaded picture stimulus in Malayalam and validate its efficacy in children with hearing impairment fitted with cochlear implant, targeting the phonemes /ʈ/ and /ɖ/. The results demonstrated that the use of thematically organized illustrations led to improvement in consonant accuracy and intelligibility in most participants. The findings revealed statistically significant improvements in both Percentage of Consonants Correct – Revised (PCC-R) and percentage of intelligibility from baseline through follow-up in most participants, confirming the clinical utility of the developed material. These results also contribute to the development of phoneme-specific, culturally appropriate, connected speech level intervention materials, specifically for children with hearing impairment fitted with cochlear implant who have speech sound errors.

Children with cochlear implants receive a degraded and spectrally compressed auditory signal through the device, which limits their access to the finer acoustic cues that distinguish phonemes with similar place features (Shannon et al., 1995; Wilson & Dorman, 2008). This results in the presence of speech sound errors. These errors seen in HI cause the speech intelligibility to reduce and therefore become a core focus of management. Speech intelligibility is influenced by many factors, including speech sound accuracy, contextual clarity, and the communicative environment (Hustad, 2007). Its importance extends beyond communication, as it directly affects a child's social, emotional, and academic development (Dickinson et al., 2007).

The retroflex stops /ʈ/ and /ɖ/ are characterized by complex lingual gestures, specifically, the curling of the tongue tip to a post-alveolar region. Their acoustic correlates, such as formant transition and spectral energy, are vulnerable to compromise in CI users due to limited channel resolution (Luo, 2020). Lighterink et al. (2025) have documented that pediatric CI users exhibit highly variable consonant production patterns, with place of articulation errors being the most frequent error category, especially for phonemes with non-visible, complex articulatory gestures. The present study's participant data supported this: all five participants presented with consistent substitution errors for /ɖ/ or /ʈ/ across all word positions at baseline, with place errors being the predominant error type in PMV analysis, consistent with the known perceptual vulnerability of retroflex phonemes in this population (Sreedevi & Mathew, 2022).

The central feature of the developed material was the selection of age-appropriate, culturally familiar, and phonemically loaded target words, embedded within meaningful thematic contexts. The target words were selected for their cultural and lexical familiarity for the targeted age group of 4 to 10 years, supported by evidence that high frequency, familiar words promote more consistent articulatory accuracy and greater generalization compared to low frequency targets (Geirut, 2007; Storkel & Morrisette, 2002). The thematic organization of words into everyday contexts such as “Bedroom”, “Tea shop” or “Garden” further supported the principle of contextual meaningfulness, allowing the child to engage in picture description rather than isolated drills. The use of onomatopoeic words was an additional feature unique to this study, as these words have been shown to facilitate sound-meaning mapping in young children and enhance articulatory imitation (Imai & Kita, 2014).

Content validation of the developed picture stimuli by SLPs yielded predominantly positive ratings, with most parameters falling under the 'Good' and 'Excellent' categories. Notably, the parental content validation resulted in an even stronger support, with 27 of 36 ratings placed in the 'Excellent' category, indicating high relevance and accessibility of the material from the caregiver’s perspective. This dual validation approach, including both clinical expert judgment and caregiver feedback, reflects a client-centered model of material development with evidence-based practice (Dollaghan, 2004; Bowen, 2015), ensuring that the stimuli are valid for both clinical and home-based use.

Quantitative outcome analysis demonstrated consistent improvement in both PCC-R and speech intelligibility scores across the eight assessment points. Mean PCC-R scores increased from 55.44% at Pre A to 75.44% at Follow-up B, while mean intelligibility scores increased from 55.24% at Pre A to 83.51% at Follow-up B. Notably, the standard deviation and interquartile range for both measures reduced progressively across the phases, indicating a reduction in participant variability as the intervention progressed. This is consistent with the premise that structured, phoneme-specific intervention reduces the heterogeneity of error patterns by providing a shared, targeted intervention framework (Flipsen, 2008). Pairwise comparisons also revealed statistically significant outcomes between baseline assessments and Post B, Follow-up A, and Follow-up B for both PCC-R and percentage of intelligibility. There were no significant differences between post and follow-up assessments, confirming that the gains achieved during intervention were well maintained.

A distinguishing feature of this study's design was the inclusion of two assessment points at each phase: two pre-intervention, two mid-intervention, two post-intervention and two follow-ups, yielding eight assessment points for each participant. This allowed for a more sensitive characterization of the outcome compared to conventional pre-post-follow-up design. Two consecutive baseline assessments provide a stable error pattern before intervention. As observed in Participant 3, who showed notable variability between Pre A (45.00%) and Pre B (57.50%) in PCC-R, dual baseline helped distinguish natural baseline variability from treatment effects and ensured that observed improvements were due to intervention rather than natural fluctuations. Similarly, mid-intervention assessments conducted after 3^{rd} and 7^{th} sessions showed how participants changed during the intervention. It enables the clinician to identify clients who respond early to the intervention approach, such as Participants 1 and 4 in the study versus those who require more intensive intervention, such as Participants 2 and 3. This multi-point assessment framework strengthens the single-subject ABA design by providing more complete within-subject data and supporting individualized clinical decision-making throughout the intervention (Horner et al., 2005).

A cross-case analysis of individual participants revealed that the type and complexity of error pattern were a key determinant of intervention outcome. Participants 1 and 4, who showed good stimulability and presented predominantly with substitution errors, achieved near-accurate or accurate production of the phoneme /ɖ/ within 4 to 7 sessions and showed strong generalization to sentence-level production. In contrast, Participants 1 and 5, both of whom presented with substitution and distortion errors reflecting greater articulatory complexity, showed a variable and prolonged course of improvement. Powell and Miccio (1996) proposed that stimulability is not only a prognostic indicator but also a target selection criterion, with non-stimulable sounds potentially requiring a longer duration of intervention. Complex articulatory errors, especially those involving distortions, which reflect motor execution difficulty rather than simple phonological errors, tend to require an extended intervention period (Dodd et al., 2008; Furlong et al., 2021). Future studies may consider intervention duration beyond 10 sessions for participants with complex error patterns (Maassen et al., 2010; Ellis, 2009). Participant 5 demonstrated a meaningful shift: the error type substitutions and distortions at baseline to distortions only by follow-up, indicating progressive approximation towards the target sound, even though accurate productions were not achieved within 10 sessions. This trajectory is supported by the motor speech literature, which documents that shifts from substitution errors towards distortions typically reflect an advanced level of articulatory precision and a closer approximation to the target (Maassen et al., 2010).

Implantation age did not emerge as a straightforward predictor of intervention outcomes in this study. Among the two oldest participants, both aged 9 years, Participant 1 was implanted at 7 years of age, comparatively a late implantation, yet demonstrated the most robust improvement across the intervention, achieving accurate production of /ɖ/ at the sentence level by 7th session and maintaining those gains through follow-up assessments. Participant 5, implanted considerably earlier at 4 years of age with a longer device usage, showed only partial improvement. This contradicts the commonly found finding in CI literature that earlier implantation and longer device usage predict speech and language outcomes (Geers et al., 2003; Niparko et al., 2010). This may be explained by other co-occurring variables: Participant 1 demonstrated strong stimulability, a consistent error pattern, and active parental and home training; all together may have overridden the advantage of longer device use in Participant 5. Participant 5, in contrast, presented with co-occurring substitutions and distortions of /ʈ/, limited stimulability, and some variability in home practice regularity. This is consistent with observations by Tobey et al. (2003), who reported that post-implant intervention intensity, consistency in using the device, and family participation were stronger predictors of speech production outcomes than implantation age alone.

The multimodal nature of the intervention, combining auditory modeling, visual picture stimuli, and tactile cues provided for the target phoneme, is effective in enhancing motor learning and articulation (Barbier et al., 2021). Picture-based stimuli that embed target phonemes within meaningful scenes support integration of both auditory and visual information during speech processing, that has been shown to enhance phonological learning in CI populations (Mayer, 2009; Bergeson & Pisoni, 2004). This is further supported by randomized controlled trial evidence from Murphy et al. (2015) and Siemons-Luhring et al. (2021), who reported significant improvements in children with speech sound disorders through intervention programs integrating visual stimuli with phonological and phonetic processing. The use of graded cueing, such as phonemic, syllabic or word-level prompts and gradually fading to sentence-level production, mirrors the principles of scaffolded learning. This scaffold helped in more naturalistic production in children, especially with limited sentence-level productions (Morrisette et al., 2003). Moreover, sentence-level output provides rich coarticulatory context for the target retroflex stop, which is more representable in everyday speech than isolated productions. Allison and Hustad (2014) suggested that utterance length and phonetic complexity significantly influence speech intelligibility in children with speech sound errors, enhancing the importance of targeting phonemes in linguistically realistic context than meaningless drills.

The positive results in this study may be attributed to the parental involvement and home training consistency. Participants 1 and 2, whose parents maintained active engagement in home-based practice using the developed stimuli, showed continued improvement beyond the intervention sessions, with PCC-R and intelligibility gains maintained across follow-up assessments. Participant 4, who also showed marked improvement at follow-up after initial slow progress, reflects the effect of sustained home training along with the structured sessions. In contrast, limited parental involvement observed in Participant 3 and 5 appeared to coincide with greater variability in the intervention outcome. Yoshinaga-Itano et al. (1998) study on early intervention for hearing impairment has established that family engagement is a core driver for speech and language outcomes. The present findings extend this evidence to the context of phoneme-specific articulation therapy in connected speech, ensuring that the developed material is accessible for home use and supports long-term generalization.

Speech intelligibility showed greater improvement than the corresponding PCC-R gains in some instances, particularly Participant 4, whose post-intervention intelligibility scores had a sharper increase than the PCC-R trajectory over the same period. This is clinically meaningful, with the literature suggesting that speech intelligibility reflects not only segmental accuracy but also prosodic, coarticulatory, and contextual factors, all of which contribute to listener comprehension (McLeod & Baker, 2017; Ertmer, 2011). As children produce target sounds in connected speech in familiar contexts, improvements in speech fluency and pragmatic coherence may contribute to perceived intelligibility.

The improvement in articulation accuracy and speech intelligibility observed across participants in the present study aligns with evidence supporting the effectiveness of phoneme-loaded, contextually rich intervention materials over traditional drill-based approaches. Kempler and Goral (2011) demonstrated that communication-based intervention, which embeds target sounds within meaningful contexts, results in greater generalization compared to repetitive word-level drills. More recently, Sindhusha and Sreedevi (2025) validated phoneme-loaded articulation stories in Malayalam for children with hearing impairment, finding greater child engagement and accurate target word identification with phoneme-dense stimuli. The convergence of positive outcomes in these studies reflects the generalizability of the phoneme-specific, naturalistic picture stimulus framework as an intervention method applicable across different phoneme classes and clinical populations.

Jesus et al. (2019) highlighted the importance of connected speech activities in facilitating the integration of learned sounds into functional communication. The literature review suggests that most available resources for sentence-level intervention are often non-standardized and lack phoneme specificity (McCormack et al., 2017). In this context, the present study addresses a significant gap mainly at two levels: the absence of standardized phoneme-specific intervention resources for retroflex stops in Malayalam, and the limited availability of validated connected speech material for children with speech sound errors. Most existing intervention materials in India are adapted from English-language resources that neither have the phonological structure of Dravidian languages nor address the specific articulatory challenges faced by CI users (Sreedevi & Mathew, 2022). The current study strongly aligns with the work of Daliya (2025), who validated the sibilant-loaded picture stimulus for Malayalam speaking children with speech sound disorders. The present work extends this by targeting a different phoneme class (retroflex stops), a different clinical population (Children with HI fitted with CI), a larger stimulus set per target phoneme (8 pictures for two phonemes), and a more robust validation design (Two assessment points for each phase).

In conclusion, the findings of the present study confirm the clinical value of structured, thematic-based picture stimuli for improving articulatory accuracy and speech intelligibility in Malayalam speaking children with hearing impairment fitted with cochlear implants. The thematically organized illustrations, incorporating sentence-level tasks, phoneme-dense target words and multimodal cueing, provided a naturalistic and valid context for connected speech intervention. Statistically significant and well-maintained improvements support the adoption of these stimuli for intervention in this population. These findings emphasize the need for developing linguistically and culturally appropriate intervention materials tailored to diverse regional populations, contexts and phonemic targets.

Chapter V

SUMMARY & CONCLUSIONS

Children with hearing impairment fitted with cochlear implants exhibit speech sound errors despite the benefits of early implantation. Among the various speech sound errors present in this population, retroflex stops are persistently misarticulated sounds due to their articulatory complexity. In Malayalam, these sounds carry high functional load , making them a clinically significant target for intervention. While traditional therapy approaches focus primarily on isolated drills or word-level production, there is a lack of standardized, structured and evidence-based materials that target these sounds in connected speech. To address this gap, there is a need for developing culturally and linguistically appropriate picture stimuli loaded with target phonemes to train children with speech sound errors for facilitating more naturalistic generalization of articulation skills (Camarata, 1993; Jesus et al., 2019).

The present study aimed to develop and validate retroflex stop-loaded picture stimulus for speech sound corrections in Malayalam for children with hearing impairment fitted with cochlear implants. The retroflex stops selected in this were /ʈ/ (voiceless) and /ɖ/ (voiced) in Malayalam. The study was conducted in two phases. In phase 1, a total of eight picture stimuli targeting the retroflex stops /ʈ/ and /ɖ/ were developed, with four stimuli representing each phoneme. Target words were selected from Malayalam children's magazines, organized thematically and distributed across all word positions. Content validation was carried out by four certified native Malayalam-speaking SLPs and three parents of children with hearing impairment. Phase 2 involved validation of the developed stimuli on five participants aged 4-10 years. A single-subject ABA design was used, and each participant received individualised intervention with the developed stimuli. A total of 10 sessions of 45 minutes duration were provided. Outcome measures included qualitative measures: SODA and PMV analysis, and quantitative measures: PCC-R and percentage of intelligibility. Measures were calculated during pre-intervention, mid-intervention, post-intervention and follow-up.

All five participants showed statistically significant improvement in PCC-R scores and percentage of intelligibility from pre-intervention to follow-up phases. Pairwise comparisons showed significant differences between pre-intervention and Post intervention, as well as between pre-intervention and follow-up assessments for PCC-R scores. A similar pattern was observed for percentage of intelligibility. SODA analysis showed substitution as the predominant error type at baseline, with omission and distortions also noted in some participants. Errors showed a progressive reduction in both frequency and severity across the intervention phases. PMV analysis indicated errors across all word positions at baseline, with a gradual reduction in positional involvement as the intervention progressed. Error type at baseline, stimulability, parental involvement, duration of treatment and child's motivation emerged as key factors influencing the outcomes of the intervention.

The retroflex stop loaded picture stimulus for speech sound corrections in Malayalam provides speech-language pathologists with a culturally appropriate, evidence-based tool for articulation intervention targeting /ʈ/ and /ɖ/ at the sentence level in children with HI . In conclusion, it bridges the gap between word-level articulation practice and generalization to connected speech, offering a functionally relevant and naturalistic communication context for this clinical population.

5.1 Limitations of the present study

- The current study was applied only for a short duration of the intervention (10 sessions).
- The follow-up assessments post-intervention were carried out in two successive weeks only, which limits understanding of long-term therapy effects.

- The study employed a single-subject design with five participants, which restricts generalizability.
- The group was not homogeneous with respect to language exposure and language age.

5.2 Clinical implications

- The study has developed a retroflex-stop-loaded picture stimulus set, which serves as a useful clinical resource for enhancing articulation skills in Malayalam-speaking children with hearing impairment.
- The material provides high opportunities for the production of retroflex stop consonants (/ʈ/ and /ɖ/).
- Contextual and theme-based pictures facilitated naturalistic learning and supported the generalization of target sound production to activities outside formal therapy tasks.
- This material can be flexibly used by both caregivers and clinicians, enabling continuity of therapy through home training in a familiar and motivating format.
- The incorporation of visual elements enhanced multisensory learning, especially for children with hearing impairment, by supporting auditory-verbal input with visual and contextual cues.
- The multi-point assessment framework provided more detailed and sensitive tracking of the participant's progress across the intervention period.
- The findings of this study may encourage the development of more standardized therapy materials for different Indian languages to facilitate target-based interventions and may also be validated for use with other populations such as cerebral palsy and intellectual disabilities.

- The stimulus set can further support other professionals, including special education teachers and auditory-verbal therapists, by providing an easily accessible visual aid in classrooms and therapeutic settings.

5.3 Future directions

- This study may be replicated with a larger sample size to strengthen statistical power and enhance the generalizability of the findings.
- Future studies may include a control group to compare picture-based intervention with conventional articulation therapy.
- The developed stimuli can be used to validate in different populations like speech sound disorders, hearing impairment fitted with hearing aids, etc.
- Participants with additional comorbidities such as autism spectrum disorder, intellectual disability, and cleft lip and palate may be included.
- The intervention duration may be extended to improve stabilization and generalization of accurate retroflex sound production in children with hearing impairment.
- The stimulus set may be expanded to include other phoneme categories such as laterals, liquids, and other stop consonants.
- Cross-linguistic and dialectal adaptations may be explored to enhance usability across related languages and cultural contexts.
- Future research may focus on developing a digital or app-based version of the picture stimuli with interactive features and real-time feedback to improve accessibility and engagement in both clinic and home-based therapy.

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APPENDIX I

IRB Approval Letter for the Dissertation

All India Institute of Speech and Hearing
(An autonomous Institute under the
Ministry of Health and Family Welfare, Govt. of India)
Center of Excellence - Assessed & Accredited by NAAC with 'A' Grade
ISO 9001:2015 Implemented Institute
Manasagangothri, Mysuru-570006

ಅಖಿಲ ಭಾರತ ವಾಕ್ ಮತ್ತು ಶ್ರವಣ ಸಂಸ್ಥೆ
ಮಾನಸಗಂಗೋತ್ರಿ, ಮೈಸೂರು–570006
अखिल भारतीय वाक् श्रवण संस्थान
मानसगंगोत्री, मैसूरु - 570 006

INSTITUTE REVIEW BOARD (IRB) APPROVAL FOR BIO-BEHAVIOURAL RESEARCH PROPOSAL INVOLVING HUMAN SUBJECTS AT AIISH

AIISH Institute Review Board (IRB)

Ref: SH/IRB/M.5/SLP.28/2025-26 **Date: 11.03.2026**

Title of the Dissertation	: Development and validation of retroflex stop loaded picture stimulus for speech sound corrections in Malayalam
Name of the Student	: Ms. Nihala Parveen V A
Guide	: Ms. Sindhusha Chandran
Co-Guide (if any)	: Dr. Priti Venkatesh
Proposed Duration of the Project	: 06 months
Source of funding	: Non-funded Master's dissertation
Estimated budget	: Nil
Reference Number of the Project	: Nil
Date on which the IRB meeting was held	: 05.03.2026
A clear statement of the decision reached IRB meeting (In the event of the proposal is not APPROVED, a statement of reasons for the same must be indicated)	**: APPROVED**
Advice & suggestions (if any)	: Nil

Signature & Name of the Member Secretary-IRB
सदस्य सचिव / Member Secretary
Dr. Animesh Barman
Professor of Audiology
संस्थान समीक्षा बोर्ड / Institute Review Board
All India Institute of Speech and Hearing, Mysore-570006
अखिल भारतीय वाक् श्रवण संस्थान
All India Institute of Speech and Hearing
मानसगंगोत्री / Manasagangothri
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APPENDIX II

Feedback questionnaire used for content validation of the material.

Name of the Validator: Designation of the Validator:

SI. No	Parameters	Very poor	Poor	Fair	Good	Excellent
1	Simplicity					
2	Familiarity					
3	Size of the picture					
4	Color and appearance					
5	Arrangement					
6	Presentation					
7	Volume					
8	Relevancy					
9	Iconicity					
10	Accessibility					
11	Flexibility					
12	Trainability					

Definition of Parameters

1. Simplicity: Are the test pictures comprehendible?

2. Familiarity: Is the stimuli familiar to the user?

3. Size of pictures: Whether the picture stimuli are of appropriate size?

4. Color and appearance: Are the picture stimuli appropriate in terms of color and dimension?

5. Arrangement: Whether the picture stimuli are within the visual field of an individual?

6. Presentation: Are the items in each section placed appropriately?

7. Volume: Is the overall picture appropriate in size?

8. Relevancy: Whether the pictures are culturally and ethically acceptable?

9. Iconicity: Does the picture stimuli appear to be recognizable and representational?

10. Accessibility: Are the picture user-friendly?

11. Flexibility: Can the stimuli be easily modified?

12. Trainability: Can the stimuli be used in for intervention purposes in different milieu?

APPENDIX III

Questions used to obtain feedback from parents regarding the developed pictures.

1) ഈ ചിത്രങ്ങൾ കുട്ടികൾക്ക് എളുപ്പത്തിൽ മനസ്സിലാവുമോ?
2) ഈ ചിത്രങ്ങൾ കുട്ടിക്ക് പരിചിതമായതാണോ?
3) ഈ ചിത്രങ്ങൾ ശരിയായ വലിപ്പത്തിലാണോ?
4) ഈ ചിത്രങ്ങൾക്ക് നല്ല നിറവും രൂപവുമുണ്ടോ?
5) കുട്ടിക്ക് കാണാൻ എളുപ്പമുള്ള സ്ഥലത്താണോ ചിത്രങ്ങൾ?
6) ഓരോ ഭാഗത്തും ചിത്രങ്ങൾ ചിട്ടയായിട്ടാണോ വെച്ചിരിക്കുന്നത്?
7) മൊത്തം ചിത്രം വലുപ്പത്തിൽ ഒത്തിരിക്കണമോ?
8) ഈ ചിത്രങ്ങൾ സംസ്കാരപരമായും ശരിയായതാണോ?
9) ഈ ചിത്രങ്ങൾ കണ്ടാൽ എന്താണെന്ന് മനസ്സിലാക്കാൻ പറ്റുമോ?
10) ഈ ചിത്രങ്ങൾ എളുപ്പത്തിൽ ഉപയോഗിക്കാമോ?
11) ഈ ചിത്രങ്ങൾ എളുപ്പത്തിൽ മാറ്റാൻ കഴിയുമോ?
12) വ്യത്യസ്ത സാഹചര്യങ്ങളിൽ പരിശീലനത്തിന് ഈ ചിത്രങ്ങൾ ഉപയോഗിക്കാമോ?

Appendix-IV a: ɖ picture stimulus 1

Bedroom

ɖ loaded target words

Initial

1. ɖo:r
2. ɖai̯no:so:r
3. ɖappa
4. ɖam ɖam
5. ɖo:ɭ
6. ɖa:gini
7. ɖo:ra
8. ɖast̪t̪əbin
9. ɖakkə
10. ɖast̪t̪ar

Final

1. kaɳɳa:ɖi
2. kaɳɳaɖa
3. ʊaɖi
4. beɖə
5. muɖi
6. sʊit͡ʃt͡ʃəbo:rɖə
7. t͡ʃeɖi
8. kuɖa
9. reɖə
10. koɖi
11. t͡ʃu:ɖə

Medial

1. beɖʃi:t̪t̪ə
2. kuɖajun̪n̪u
3. sai̯ɖə ʈe:biɭ
4. meɖisin
5. kaɖala:sə
6. uɖuppə
7. kuɖukkə
8. st̪t̪aɖi ʈe:biɭ
9. guɖəbo:jə
10. pau̯ɖar
11. paɖam
12. kuɖukka
13. paɖikkun̪n̪u
14. beɖru:m

Appendix-IV b: ɖ picture stimulus 2

Kitchen

ɖ loaded words

Initial

1. ɖai̯niŋə ʈeːbiɭ
2. ɖoːɳaʈʈ
3. ɖappa
4. ɖoːr
5. ɖisambar
6. ɖaːm
7. ɖoːkʈar
8. ɖid͡ʒiʈːal
9. ɖaːnsə

Final

1. pat͡ʃt͡ʃaɖi
2. kit͡ʃt͡ʃaɖi
3. muɭakə poɖi
4. maɲɲaɭ poɖi
5. muːɖi
6. Ʊaːɖi
7. kaboːrɖə
8. kaɖan̪n̪al kuːɖə
9. kaɳɳaːɖa
10. paɖi
11. aɖipiɖi

Medial

1. aɖukkaɭa
2. paɖikkun̪n̪u
3. kaɖukə
4. aɖuppə
5. pappaɖam
6. kaɖan̪n̪al
7. t̪uɖukun̪n̪u
8. piɖit͡ʃt͡ʃmaːt̪t̪un̪n̪u
9. aɖakkun̪n̪u
10. kiɖakkun̪n̪u
11. uɖuppə
12. kaɖuʋa
13. reːɖijoː

Appendix-IV c: ɖ picture stimulus 3

Tea shop
ɖ loaded words

Initial

1. ɖeːʋiɖə
2. ɖisambar
3. ɖoːr
4. ɖoːgə

Medial

1. kaɖala
2. Kaɖala miʈʈaːji
3. reːɖijoː
4. kuɖam
5. iɖijappam
6. kuɖikkun̪n̪u
7. kaɖikkun̪n̪u
8. pappaɖam
9. saŋkaɖam
10. paːɖam
11. t̪oɖun̪n̪u
12. t͡ʃaːɖun̪n̪u
13. paɖakkam
14. paɖaʋalaŋŋa

Final

1. t͡ʃaːjakkaɖa
2. reɖə
3. muːɖi
4. uɻun̪n̪ə ʋaɖa
5. paɾippə ʋaɖa
6. laɖu
7. t͡ʃaːjappoɖi
8. breɖə
9. t͡ʃuːɖə
10. soːɖa
11. fraiɖeː
12. t̪aːɖi
13. roːɖə
14. ʋiːɖə
15. t͡ʃeɖi
16. aːɖə

Appendix-IV d: ɖ picture stimulus 4

Beach side
ɖ loaded words

Initial

1. ɖo:ɭfin
2. ɖi (letter)
3. ɖo:ɭar

Medial

1. kaɖal
2. o:ɖun̪n̪u
3. t͡ʃa:ɖun̪n̪u
4. fuɖbo:ɭ
5. kuɖilukaɭ
6. ʋi:ɖukaɭ
7. kat͡ʃt͡ʃaʋaɖam
8. kaɖala
9. kaɖuʋa
10. ko:ɖa:li
11. apakaɖam
12. ku:ɖinikkun̪n̪u
13. aɖibʱa:gam
14. kiɾi:ɖam
15. iɖikkun̪n̪u

Final

1. reɖə
2. ko:ɖi
3. Kaɾaɖi
4. ku:ɖə
5. koɖi
6. kaɖa
7. t͡ʃu:ɖə
8. ka:ɖə
9. maɾat̪t̪aɖi
10. ro:ɖə
11. mukʰamu:ɖi
12. pe:ɖi
13. Ʊaɖi
14. t̪a:ɖi

Appendix-V a: t̪ picture stimulus 1

Tuition centre

t̪ loaded words

Initial

1. t̪i:t͡ʃt͡ʃar
2. t̪en
3. t̪a:bə
4. t̪e:biɭ
5. t̪ailsə
6. t̪ed̪i
7. t̪aimt̪e:biɭ
8. t͡ʃaʋit̪t̪i
9. t̪estt̪ət̪ju:bə
10. t̪int̪u
11. t̪o:m
12. t̪o:ppar

Final

1. pot̪t̪ə
2. et̪t̪ə
3. mut̪t̪a
4. ko:t̪t̪ə
5. ro:bo:t̪t̪ə
6. po:t̪t̪ə
7. pet̪t̪i
8. t͡ʃaʋit̪t̪ukut̪t̪a

Medial

1. kut̪t̪ikaɭ
2. pat̪t̪am
3. n̪o:t̪t̪bukkə
4. bo:t̪t̪il
5. sa:nit̪aisar
6. ot̪t̪it͡ʃt͡ʃu
7. Uat̪t̪am
8. Ot̪t̪agam
9. sello:t̪e:ppə
10. pat̪t̪ə sa:ri
11. pot̪t̪it͡ʃu

Appendix-V b: ʈ picture stimulus 2

Hotel

ʈ loaded words

Initial

1. ʈai̯lsə
2. ʈo:m
3. ʈelifo:ɳ
4. ʈakə ʈakə
5. ʈi:ʋi
6. ʈaʋal
7. ʈe:biɭ
8. ʈju:blai̯t̠t̠ə
9. ʈai̯

Medial

1. ɦo:ʈʈal
2. karʈʈan
3. sju:ʈʈke:sə
4. paʈʈa:ɭakka:r
5. ʋeɭɭat͡ʃt͡ʃa:ʈʈam
6. bo:ʈʈil
7. t͡ʃaʈʈukam

Final

1. fo:ʈʈo:
2. t̪aʈʈi
3. poʈʈi
4. puʈʈə
5. poro:ʈʈa
6. roʈʈi
7. muʈʈa
8. gɾi:n ʈi:
9. d͡ʒiɲd͡ʒəɾ ʈi:
10. t͡ʃeɖi t͡ʃaʈʈi
11. ko:ʈʈə
12. n̪et̠t̠i

Appendix-V c: ʈ picture stimulus 3

Utility room
ʈ loaded words

Initial

1. ʈo:jlat̲t̲ə
2. ʈa:pə
3. ʈis̪ju:
4. ʈe:biɭ
5. ʈu:ɭsə
6. ʈelifo:ɳ
7. ʈe:ppə
8. ʈo:rt͡ʃt͡ʃə
9. ʈi:m
10. ʈis̪arʈʈə
11. ʈeɖi
12. ʈikkat̲t̲ə

Medial

1. fuʈbo:ɭ
2. sʋeʈʈar
3. sju:ʈʈke:sə
4. n̪o:ʈʈəbukkə
5. t̪oʈʈil

Final

1. t͡ʃaʋit̲t̲ukuʈʈa
2. pu:ʈʈə
3. peʈʈi
4. poʈʈi
5. t͡ʃuɾuʈʈi
6. t̪i:ppeʈʈi
7. fo:ʈʈo:
8. a:ɳkuʈʈi
9. t͡ʃaʋiʈʈi

Appendix-V d: ʈ picture stimulus 4

Garden
ʈ loaded words

Initial

1. ʈo:rt͡ʃt͡ʃə
2. Ʈiʃu:m
3. Ʈajar
4. ʈo:jsə
5. ʈe ʈe
6. ʈai̯
7. ʈe:biɭ

Medial

1. t̪o:ʈʈam
2. poʈʈa:t̠t̠o:
3. ʈoma:t̠t̠o:
4. t̪o:ʈʈakka:ɾan
5. t͡ʃe:ʈʈan
6. keʈʈun̪n̪u
7. Paʈʈam
8. sa:niʈai̯sar
9. Muʈʈa:ji
10. t̪aʈʈam
11. u:ʈʈi ka:ɾat̠t̠ə
12. luʈʈa:ppi

Final

1. Kaʈʈa
2. Mammu:ʈʈi
3. muʈʈə
4. Kuʈʈa
5. Pa:ʋakkuʈʈi
6. paʈʈi
7. ko:ʈʈə
8. pa:ʈʈə
9. ʋeʈʈi