Development of High-Frequency Wordlists for Children in Malayalam

ASWINLAL K

Registration No: P01II24S023007

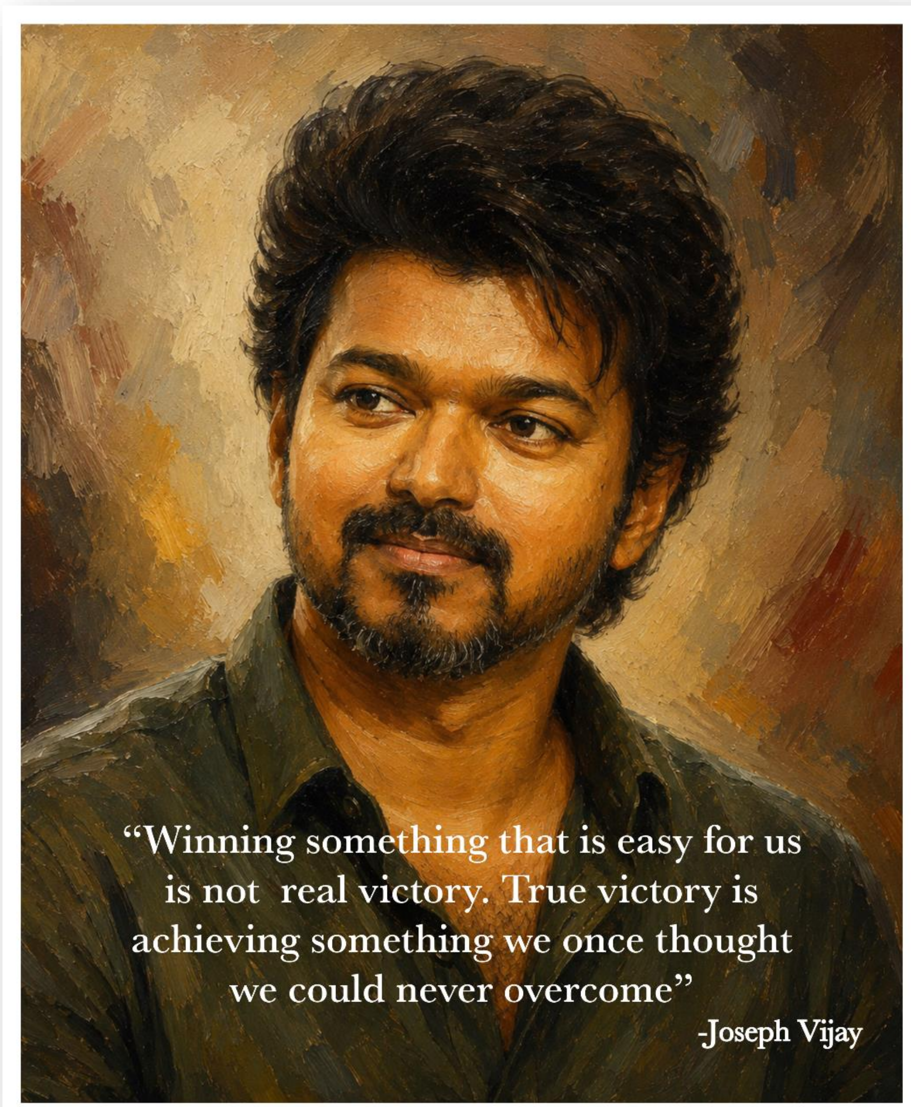
A Dissertation Submitted in Part of Fulfilment of the Degree of
Master of Science
(Audiology) University of
Mysore

All India Institute of Speech and Hearing

Manasagangothri, Mysuru -570006

June, 2026

Dedicated to my parents, friends, teachers and beloved guide for their constant support and encouragement throughout this journey.



CERTIFICATE

This is to certify that this dissertation entitled **"Development of High-Frequency Wordlists for Children in Malayalam"** is a bonafide work submitted as part of fulfilment of the degree of Master of Science (Audiology) of the student with Registration Number **P01II24S023007**. This has been carried out under the guidance of a faculty of this institute and has not been submitted earlier to any other university for the award of any other Diploma or Degree.

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CERTIFICATE

This is to certify that this dissertation entitled "**Development of High-Frequency Wordlists for Children in Malayalam"** has been prepared under my supervision and guidance. It is also being certified that this dissertation has not been submitted earlier to any other university for the award of any other Diploma or Degree.

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DECLARATION

This is to certify that this dissertation entitled "**Development of High-Frequency Wordlists for Children in Malayalam”** is the result of my own study under the guidance of Dr. Chandni Jain, Associate Professor of Audiology, All India Institute of Speech and Hearing, Mysuru and has not been submitted earlier to any other university for the award of any other Diploma or Degree.

Mysuru
June, 2026

Registration No: P01II23S023033

Acknowledgements

I express my deepest gratitude to my guide, ***Dr. Chandni Jain****, whose patience, dedication, and unwavering belief in this work illuminated every step of this journey. With remarkable precision and tireless effort, she transformed challenges into opportunities for learning and growth. Her pursuit of excellence, prompt guidance, and constant encouragement inspired me to strive beyond my limits and shape this work into its best form.*

I express my sincere gratitude to ***Dr. M. Pushpavathi****, Director of the All India Institute of Speech and Hearing (AIISH), Mysuru, for providing the facilities, resources, and academic environment necessary for the successful completion of this dissertation.*

I express my deepest gratitude to my ***Achan****,* ***Amma****,* ***Appuettan*** *and* ***Harshechi****, whose unwavering love, endless support, and steadfast belief in me have been the foundation of every step I have taken. Their constant reminder to hold my head high and face life with courage has been a guiding light throughout my journey. A special mention goes to* ***Rocky****, whose silent companionship, boundless affection, and joyful presence brought comfort and happiness even during the most demanding days.*

I extend my heartfelt gratitude to ***Dr. Sandeep Sir****, whose passion for innovation and relentless pursuit of perfection have been a constant source of inspiration. His guidance and support have not only shaped my academic journey but have also encouraged me to strive for excellence in all that I do..*

I extend my deepest gratitude to ***Dr. Indira C. P****., whose kindness and support reached far beyond academia. During moments of uncertainty and struggle, her guidance, compassion, and unwavering faith in me became a source of strength. Her presence will always remain one of the brightest lights in my journey.*

I would like to express my sincere gratitude to the ***Principal of Kizhur GUPS*** *and* ***Mr. Sajeevan*** *for granting permission and extending their support for data collection. I also extend my heartfelt thanks to all the children and their parents for their enthusiastic participation, cooperation, and valuable contribution to this study. Their support was essential to the successful completion of this research.*

I would like to express my sincere gratitude to ***Dr. Vasanthalakshmi*** *for her valuable guidance and support in the statistical analysis of this study*

I would like to express my sincere gratitude to ***Dr. Saransh Jain*** *for his valuable guidance and assistance with the MATLAB-related aspects of this study. His expertise, support, and willingness to clarify technical concepts greatly contributed to the successful completion of this work.*

I sincerely thank ***Dr. Niraj Kumar Singh****, Head of the Department of Audiology, and* ***Dr. N. Devi****, Head of the Department of Prevention of Communication Disorders, for their support and encouragement. I am especially grateful to the Department of Prevention of Communication Disorders for providing the equipment required for data collection.*

I would like to express my sincere gratitude to ***Dr. A. Nambi****, JRF* ***Ms. Gayathri****,* ***Dr. Vikas****,* ***Dr. Sharath****,* ***Dr. Arunraj****, and* ***Ms. Suma*** *for their support, encouragement, and assistance throughout this study. Their guidance, valuable suggestions, and willingness to help whenever needed are greatly appreciated.*

I would like to express my heartfelt gratitude to **Anees, Shyam, Vismaya, Ashish, Praveenettan, Shyamettan, Rajils, Josettan, Adhil, Sahal, Abu** and **Surabhi** whose friendship has been one of the greatest blessings of my journey. Through moments of joy and uncertainty, they stood beside me with unwavering support, laughter, encouragement, and belief. Their presence turned ordinary days into cherished memories, lightened the weight of challenges, and made this journey not only meaningful but truly beautiful.

A special note of gratitude to **Nihala** for her unwavering support, encouragement, and friendship throughout this journey. Her constant presence has meant a great deal to me, and I thank her from the bottom of my heart. I am equally grateful to **Parvathi** for her support and friendship. I also sincerely thank her for serving as the speaker for the stimulus recordings used in this study, making an important contribution to this research.

I would like to express my heartfelt gratitude to my dissertation partner, **Anagha**, for her support, cooperation, and companionship throughout this journey. Sharing this experience with her made the challenges easier and the successes more meaningful, and I will always cherish the memories we created together.

I would also like to express my heartfelt gratitude to my batch, **Celestials**, for the friendship, support, laughter, and countless memories shared throughout this journey. Being a part of this wonderful group made my academic experience truly enriching and memorable. I would like to extend my sincere gratitude to my batchmates **Hiba, Amal, Ajith, Manju, Dinesh, Nitish, Uday, Aksha, Preksha, Yashas, Neba, Adhila, Agraja** and **Neeraja** for their companionship, support, and the wonderful memories we shared throughout our academic journey. Their friendship and encouragement made this experience both enjoyable and memorable.

I extend my heartfelt gratitude to my beloved batch, **ECHO**, for the friendships, memories, and moments that continue to echo through my journey. The laughter we shared, the challenges we overcame, and the bonds we built have left an everlasting mark on my heart.

I would like to extend my heartfelt gratitude to my beloved juniors and the members of the Room No. 114 WhatsApp group—**Jessin, Ihsan, Abdu, Shahul, Shahal, Adwaith, Hadi, Beeran, Nihal, Shantha, Arshad, Ajnas** and **Irfan** —for bringing immense joy, energy, and countless memorable moments into my life. Their friendship, support, and companionship made this journey much more enjoyable. I am especially grateful to **Ihsan** for generously providing his laptop for my dissertation work, and to **Adwaith** and **Hadi**, whose affection, friendship, and cheerful presence have made them truly special to me.

I would like to express my heartfelt gratitude to **Karthika, Lavanya, Nitha, Aslin, Ananya Sooraj, Drishti, Safna, Ananya, Anakha, Namratha, Sumanyu, Rena, Sana, Ansha, Nuha,** and **Naja** for filling my college years with friendship, kindness, laughter, and cherished memories. Their presence added color to ordinary days and warmth to difficult ones, and I will always be grateful for crossing paths with such beautiful souls.

Finally, I extend my heartfelt gratitude to my fellow inmates of **Bodhi Gents Hostel**, the **staff** and **students of AIISH**, and all those who, in ways big and small, extended a helping hand, offered support, encouragement, and kindness throughout my journey.

To a chapter that quietly changed the course of my story, thank you. What once felt like a storm became the wind beneath my wings, teaching me how to rise stronger, stand taller, and find strength within **myself**.

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Abstract

Aim: *The present study aimed to develop high-frequency wordlists in Malayalam for speech identification testing in children.*

Methods: *The present study was carried out in two phases: (1) Development of high-frequency word lists for children, and (2) Standardization of the developed test material. Initially, high-frequency Malayalam words were identified and categorized into bisyllabic and trisyllabic word lists. Familiarity of the selected words was assessed through familiarity ratings obtained from native Malayalam-speaking children to ensure lexical appropriateness and ease of recognition. Acoustic analysis of the recorded stimuli was further performed using Long-Term Average Speech Spectrum (LTASS) and spectral centroid measures to evaluate spectral characteristics and ensure relative equivalence across the developed lists. The developed high-frequency lists were then administered to 100 typically developing Malayalam-speaking children aged between 7 and 11.11 years under both quiet and noise listening conditions. Participants were grouped according to age, and each group consisted of 20 participants with an equal distribution of males and females. Speech Identification Scores (SIS) scores were obtained for all the developed lists. Statistical analysis was performed to examine the effects of age, gender, and listening condition on SIS performance, as well as to determine equivalence across the developed lists.*

Results: *Statistical analysis revealed no significant gender-wise differences in SIS under both quiet and noise conditions across all age groups. However, significant age-related differences were observed, with older children showing better performance than younger children in both listening conditions. SIS scores were significantly higher in quiet than in noise across all developed lists. The developed Malayalam high-frequency word lists demonstrated high* *equivalency under both quiet and noise conditions, with only minor differences observed in one age group that were not significant after Bonferroni correction. These findings indicate that the developed SIS lists are equivalent and clinically useful for speech identification assessment in children.*

Conclusion: *To conclude the developed high frequency word lists showed relative equivalence and may be considered useful for clinical and research assessment of speech identification abilities in Malayalam-speaking children.*

Key words: Speech Identification Scores (SIS), high-frequency word lists, pediatric speech perception, Malayalam.

Chapter 1

Introduction

Speech perception is an auditory process that enables a person to detect, discriminate, and comprehend speech signals, forming the basis of human communication. In children, good speech perception is critical for the development of language, academic skills, and social interaction (McRoberts, 2008). During early childhood, the auditory system undergoes significant maturation, and the ability to accurately perceive speech plays a vital role in acquiring phonological, lexical, semantic, and syntactic knowledge (Kral & Sharma, 2012). Any difficulty in speech perception during this critical period can significantly affect speech and language development, thereby accurate assessment of speech perception abilities in pediatric populations is very important for the proper development of language and has a huge impact on quality of life.

Pure-tone testing provides information about hearing thresholds but does not show how well a person can understand speech in daily situations (Emanuel, 2005). For this reason, speech perception testing is an important part of the audiological assessment. It provides insight into how effectively a person can detect and recognise speech sounds, a skill necessary for everyday communication (Killion et al., 2004). Assessment of speech perception is done using standardized test materials, which include syllables, words, and sentences. Among these, word-based materials are widely used as they are simple to use and give reliable results when evaluating speech recognition abilities across different age groups (Mackersie et al., 2020). Word recognition tests give a better view of an individual's speech processing capabilities and are frequently used in both clinical diagnostics and rehabilitation monitoring. The effectiveness of such assessments mainly depends on the selection of appropriate test material or stimuli that are representative, familiar, and linguistically relevant to the target population.

High-frequency word lists, which consist of commonly used words in a language, have been proven to be a useful tool in speech audiometry testing (Storkel, 2004). These words are commonly used in daily communication and academic settings, making them more familiar to listeners, particularly children. The use of high-frequency words provides strong real-life relevance and ensures reliable, consistent responses during audiological testing (Storkel, 2004). This is especially important when there is high-frequency hearing loss, where individuals experience difficulty perceiving high-frequency consonants that are highly important for speech understanding, and the use of familiar, high-frequency words in assessment can help provide a more accurate idea of these deficits (Walker, 2023).

However, the development of speech perception materials is language-specific, and they should contain the overall phonological and lexical characteristics of the specific language in which it is being developed. Standardized materials developed in one language cannot be directly used in any other language for assessment due to differences in language structure and patterns of word usage. This shows that developing the wordlists linguistically and culturally relevant test materials are very important (Chue et al., 2024; Vainutienė et al., 2024) for accurate assessment in speech perception assessment.

In India, there is diversity of speech perception tools in regional languages. Malayalam, being one of the major Dravidian languages, possesses unique linguistic features that require the development of language-specific test materials for assessment. However, there is a limited availability of standardized high-frequency word lists exclusively designed for Malayalam-speaking children. This gap is especially critical for children, who depend on familiar, high-frequency words to develop listening, speaking, and reading skills that support education and daily communication (Schmitt et al., 2011). This lack of appropriate materials makes the accurate assessment of speech perception abilities very difficult in this population.

Although other studies have focused on speech perception assessment and material development in various other languages (Chue et al., 2024; Vainutienė et al., 2024), there remains a gap in research on the development of high-frequency, child-appropriate word lists, especially in many Indian languages, including Malayalam. The lack of such standardized materials reduces the effectiveness of clinical assessment and may affect the accuracy of diagnosis and intervention planning. Therefore, the present study aims to develop a high-frequency word list in Malayalam for children, ensuring linguistic relevance and clinical applicability. The development of such a tool is expected to improve the assessment of speech perception abilities and contribute to better audiological practice.

1.1 Need for the Study

High-frequency words are the most common words used in everyday conversation. Due to their frequent occurrence, they serve as a sensitive tool for identifying hearing difficulties, particularly in individuals with high-frequency hearing loss (Lutman & Haggard, 1983; Storkel, 2004). This is very much significant for children, who rely mainly on familiar, high-frequency words as the building blocks of their language development (Ambridge et al., 2015; Walker, 2023). When a person with high-frequency hearing loss finds it difficult to recognize these commonly used words, it strongly points towards a communication difficulty that can affect everyday interactions of that person. Hence including high-frequency word lists into speech testing, therefore, increases the accuracy and reliability of assessment.

Further, with over 35 million people speaking Malayalam (*Census (2011) Government of India.*, 2011), there is an urgent need for a standardised high-frequency word list that shows the linguistic and cultural context of native speakers across different age groups, mainly children. Currently, there is a significant lack of such specifically designed and culturally appropriate speech test materials for people who speak Malayalam. This is a major gap in our clinical tools available, making it difficult to get a complete idea of a Malayalam speaker's hearing abilities (Boothroyd, 1991).

To solve this problem, there is a clear need for speech perception test materials that are specifically developed using high-frequency words in Malayalam. High-frequency words are commonly used in everyday communication and are usually learned during early childhood. Because of this, they are more familiar and easier to recognize, which makes them suitable for speech audiometry testing (Nation, 2006). When familiar words are used for testing, children will respond more accurately and reliably, and the results will reflect their actual listening ability rather than their vocabulary knowledge (Garadat et al., 2021). At present, the availability of Malayalam speech materials is very limited (Kumar & Mohanty, 2012). The existing materials are restricted and cannot be used for different age groups, or are not developed based on word frequency. As a result, these materials may not accurately represent real-life communication situations or be age-appropriate. This creates a gap between clinical assessment tools and the everyday communication needs of Malayalam-speaking children.

Research in speech audiometry has shown that the choice of test materials plays an important role in the accuracy of assessment. Materials that are not appropriate for the listener's language age or familiarity level can lead to wrong results and misinterpretation of auditory abilities (Boothroyd, 1991). Therefore, it is important to develop speech materials that are linguistically appropriate and based on familiar words. Developing a standardized high-frequency word list in Malayalam would improve the accuracy of speech audiometry testing. It would provide clinicians with a more reliable tool for assessing speech perception, especially in children and in individuals with high-frequency hearing loss. Such a tool would be able to address the real-world scenarios and support more effective clinical decision making.

1.2 Aim of the Study

This study aimed to develop high-frequency Malayalam wordlists for speech audiometry in children.

1.3 Objectives of the Study

- To develop high-frequency Malayalam wordlists for children that capture commonly used words in daily communication.
- To develop norms for the developed Malayalam high-frequency word lists in quiet and noise for children.
- To check the equivalency of the different lists of the developed test material.
- To assess the effect of age, gender and listening condition on the developed test material.

Chapter 2

Review of Literature

Speech audiometry is an essential component of audiological assessment; it gives information about an individual's ability to perceive and recognize speech. Speech audiometry involves assessment of sensitivity as well as speech clarity (Plomp, 1978). Early efforts in the development of speech audiometry materials mainly focused on creating standardized and reliable word lists (Hirsh et al., 1952). Earlier studies introduced the concept of phonetically balanced (PB) word lists, in which the distribution of phonemes in the test materials reflected their occurrence in everyday speech (Hirsh et al., 1952).

Speech audiometry consists of tests that assess different aspects of speech perception and recognition. Commonly used speech audiometric tests include Speech Detection Threshold (SDT), Speech Recognition Threshold (SRT), Speech Identification Score (SIS), and speech-in-noise tests. SDT assesses the lowest intensity level at which the presence of speech can be detected. It is obtained by presenting speech stimuli at decreasing intensity levels and finding the lowest level at which an individual can detect the presence of speech at least 50% of the time, and recognition of speech is not necessary. SRT measures the minimum intensity level at which speech can be correctly recognized 50% of the time using spondee words. SIS evaluates an individual's ability to correctly identify phonetically balanced monosyllabic words presented with certain intensity (Gelfand, 2016; Katz, 2014) above the threshold levels and obtained by calculating the percentage of correct responses. This test provides information about speech clarity and speech discrimination ability.

Speech-in-noise tests include tests such as the Speech Perception In Noise Test (SPIN) (Kalikow et al., 1977), Hearing in Noise Test (HINT) (Nilsson et al., 1994) and Quick Speech-in-Noise Test (QuickSIN) (Killion et al., 2004). The SPIN test is done by presenting phonetically balanced (PB) words in the presence of background noise at a fixed signal-to-noise ratio (SNR), commonly 0 dB SNR, and calculating the percentage of words correctly identified by the individual. HINT is done by presenting sentences in quiet and in background noise to determine the minimum SNR at which the individual can correctly repeat 50% of the sentences. QuickSIN is done by presenting sentences with increasing levels of background babble noise and calculating the SNR loss based on the number of keywords correctly identified. These tests assess the listener's ability to perceive speech under adverse listening conditions, thereby representing real-world hearing performance (Martin & Clark, 2015).

Further, phonemic balance was initially considered an important criterion for a speech audiometric assessment wordlist; later research suggested that it may not fully represent real-life speech perception. Boothroyd (1991) stated that speech audiometry should assess real-world listening ability, not the isolated phonetic performance. This gradually led to a shift of focus from purely phonetic considerations to more listener-centred factors such as familiarity and everyday language use.

Speech audiometry evaluations are commonly done using different types of test materials, which include syllables, words, and sentences, to evaluate an individual's ability to perceive and understand speech. Among these materials, word-based materials are majorly used in clinical practice due to their easiness and effectiveness in assessing speech recognition ability (Wilson & McArdle, 2005). A direct measure of an individual's auditory performance can be achieved by word recognition testing without having much influence of contextual clues like sentences, hence making it a reliable tool for understanding difficulties in real life situations (Wilson & McArdle, 2005).

Compared to sentence-based materials, word lists require minimal linguistic and cognitive processing by the individual; this makes the material useful in testing wide range of population including children (Boothroyd, 1991; Wilson & McArdle, 2005). Boothroyd (1991) highlighted that word recognition measures are essential in evaluating real-life hearing ability, as they allow clinicians to assess speech perception without involving higher-level language processing. This is especially important in pediatric populations, where language skills are still developing.

Additionally, standardized word lists are required for consistency in testing procedures, and this allows for comparison across individuals and clinical settings. The use of standardized and validated test materials will give reliable and accurate speech audiometry results. These characteristics highlight the importance of standardized word-based materials as a basic component of speech audiometry.

2.1 Importance of High Frequencies in Speech Intelligibility

High-frequency components of speech play a crucial role in speech intelligibility, especially in the perception of consonants. While low-frequency components majorly contribute to the perception of speech loudness and providing information about vowel, important cues for differentiating consonants such as /s/, /f/, /ʃ/, and /t/, are from high-frequency energy in the spectra, which are important for good speech clarity (Lutman & Haggard, 1983). These consonants provide fine structural information that makes the listeners differentiate between words that may sound very similar.

Research has shown that the contribution to speech intelligibility that each frequency region of a speech spectra gives are not uniform. The band-importance function studies by Studebaker and Sherbecoe (1991) demonstrated that higher frequency regions are major contributors of overall speech understanding, especially in the presence of background noise. Similarly, French and Steinberg (1947) showed that reducing high-frequency information in speech stimuli leads to a reduction in speech intelligibility, even when low-frequency components remain unchanged.

The importance of high-frequency information is more evident in individuals with high-frequency hearing loss. Individuals with such hearing loss mainly report that they can hear speech, but they are not able to understand it clearly, especially when the environment is noisy. This is because high-frequency hearing loss majorly affects the perception of consonant sounds in speech, which are critical for speech discrimination and identification (Moore, 2013). As a result, even mild high-frequency impairment can have a huge impact on communication in real-world listening situations and lead to a poor quality of life.

Studies have further shown the role of high-frequency cues in difficult listening environments. Research has shown that a good amount of high-frequency information (above 4 kHz) in a speech can improve speech perception, mainly in noisy situations and for differentiating fricative sounds (Monson et al., 2014). This shows the importance of having high-frequency components when designing speech audiometry materials, especially for evaluating real-life hearing abilities.

The literature consistently says that high-frequency components are essential for accurate speech perception and for good intelligibility. Their role becomes even more crucial in complex listening conditions and in populations with hearing impairment. Therefore, having high-frequency information in speech materials can improve clinical relevance and overall sensitivity of speech perception assessment.

2.2 Acoustic Validation of High-Frequency Speech Stimuli

Acoustic validation is an important step in the development of speech audiometry materials. Acoustic measures such as Long-Term Average Speech Spectrum (LTASS) and spectral centroid analysis are commonly used to evaluate the frequency characteristics of speech stimuli. These measures help determine whether the developed materials contain sufficient high-frequency acoustic information required for assessing speech perception abilities, especially in individuals with high-frequency hearing loss.

2.2.1 LTASS

LTASS gives the average distribution of speech energy across different frequencies regions over a long speech sample. LTASS is generally used for acoustics analysis of speech materials and to identify the frequency regions which carry maximum speech information. Studies have shown that conversational speech mainly contains energy between 250 Hz and 8 kHz, with important speech cues for speech perception present in the higher frequencies (Byrne et al., 1994). LTASS is obtained by averaging the spectral energy of multiple speech frames across time and can be represented as:

$$LTASS(f) = \frac{1}{N}\sum_{i=1}^{N} S_i\,(f)$$

where $LTASS(f)$ shows the long-term average spectrum at frequency f, $S_i(f)$represents the spectral magnitude of the i^{th}speech frame, and Nrepresents the total number of speech frames analyzed.

LTASS analysis is mainly used in the development and validation of speech audiometry materials, especially high-frequency speech test materials. It helps to find whether the developed speech stimuli contain required high-frequency acoustic information for assessing speech perception abilities in individuals with hearing impairment. High-frequency consonants such as /s/, /f/, /ʃ/, and /t/ contribute significantly to speech intelligibility and are especially important in noisy listening conditions. Therefore, speech materials with greater spectral energy above 2 kHz are considered more sensitive for evaluating high-frequency hearing loss and real-life hearing performance or abilities

2.2.2 *Spectral Centroid Analysis*

The spectral centroid shows the spectral center of mass of the spectrum and is related to the perceived brightness of a sound. The higher the centroid, the brighter or sharper the sound (Müller, 2015; Schubert & Wolfe, 2006). Giannakopoulos and Pikrakis (2014) explained that the spectral centroid is the centre of 'gravity' of the spectrum. The value of spectral centroid, C_i, of the ith audio frame is defined as:

$$C_i = \frac{\sum_{k=1}^{Wf_L} kX_i(k)}{\sum_{k=1}^{Wf_L} X_i(k)}$$

Spectral spread is the second moment of the spectrum. In order to compute it, one has to take the deviation of the spectrum from the spectral centroid, according to the following equation:

$$S_i = \sqrt{\frac{\sum_{k=1}^{Wf_L} (k\text{-}C_i)^2 X_i(k)}{\sum_{k=1}^{Wf_L} X_i(k)}}$$

By selecting words with spectral centroids consistently above 2 kHz, HF-SITs eliminate this redundancy and force the listener to rely on high-frequency acoustic cues for correct word identification. This improves the diagnostic sensitivity of the test and enhances its utility for hearing aid evaluation, as significant differences between aided and unaided scores on HF-SIT have been reported in individuals with sloping SNHL.

2.3 Review of High-Frequency Speech Tests

Different high-frequency speech tests have been developed in many languages including English as well as few Indian languages. These materials differ with respect to language or length of the stimuli used (word or sentence). The stimulus in these materials is designed in such a way that it addresses the speech understanding difficulties caused by high frequency components in the speech. The various speech audiometry test materials developed in English and various Indian languages are summarized in Table 2.1 and Table 2.2

Table 2.1

Summary of different high frequency tests in English

Author & Year	Test/Material	Objective	Findings
Gardner (1971)	High-Frequency Consonant Discrimination Word List	Assess high-frequency hearing loss and hearing aid performance	Useful in identifying high-frequency speech perception deficits.
Pascoe (1975)	Pascoe's High-Frequency Word Test	Improve speech audiometry sensitivity for hearing aid evaluation	Effective for assessing speech understanding, especially in noise.
Dennison and Kelly (1978)	High-Frequency Consonant Word Lists	Assess speech perception in hearing aid users	Sensitive for aided and unaided speech perception assessment.
Sudipta (2006)	High Frequency-English Speech Identification Test (HF-ESIT)	Assess high-frequency speech perception clinically	Useful clinical tool for identifying high-frequency speech perception difficulties.

Table 2.2

Summary of different high frequency test in Indian languages

Author & Year	**Test/Material**	**Objective**	**Findings**
Kavitha (2002)	High Frequency-Kannada Speech Identification Test (HF-KSIT)	Assess high-frequency speech perception in Kannada speakers	Effective in identifying high-frequency speech perception difficulties.
Sinthiya (2009)	Tamil High-Frequency Speech Identification Test	Assess high-frequency speech perception in Tamil speakers	Clinically useful for identifying high-frequency speech perception deficits.
Ratnakar (2010)	Telugu High-Frequency Speech Identification Test	Assess speech perception in Telugu-speaking hearing-impaired individuals	Useful for clinical evaluation of auditory performance.
Kumar et al. (2016)	Marathi Speech Identification Materials	To develop Marathi speech materials for audiometry	Highlighted importance of language-specific materials.
Chintamani (2017)	High Frequency Word Identification Test for Children in Indian-English (HF-WITCIE)	Assess high-frequency speech perception in children in Indian English	Useful for pediatric speech audiometry assessment.
Ghimire and Prabhu (2018)	Nepali High-Frequency Word Lists	Assess high-frequency speech perception in Nepali speakers	Sensitive in identifying high-frequency speech perception deficits.
Desai and Deshpande (2024)	Early Speech Perception Test in Gujarati	Assess speech perception in preschool children	Reliable and useful for pediatric assessment.
Lalchewilena (2012)	Mizo High Frequency Speech Identification Test (MHF-SIT)	Assess high-frequency speech perception in native speakers of Mizo	Useful for evaluating speech perception difficulties associated with high-frequency hearing loss
Hmangte (2012)	Manipuri High Frequency Speech Identification Test	Assess high-frequency speech perception in native speakers of Manipuri language	Useful for assessing individuals with high-frequency hearing loss.

2.4 Review of Speech Audiometry Materials in Malayalam

Malayalam is a language spoken in Kerala a state India. It is considered one of the major South Indian languages and that has a rich phonological and linguistic structure. Malayalam contains a large collection of vowels and consonants, including several fricatives, nasals, laterals, and retroflex sounds that are the major contributor of its unique acoustic characteristics (Asher & Kumari, 1997). Development of language specific materials are important for accurate assessment. There have been several materials developed in Malayalam for speech audiometry over the years. These materials are developed for assessing both adults as well as children. Most of these materials focus on improving clinical applicability, linguistic familiarity, and pediatric assessment.

One of the important pediatric speech perception materials developed in Malayalam is the Picture Test of Speech Perception in Malayalam for Children (Mathew & Yathiraj, 1996). The material was specifically designed for Malayalam-speaking children using familiar and picturable Malayalam words. The selected words were commonly used words that could be easily represented through pictures were selected for the test. The developed material consisted of 50 words in two list containing familiar nouns and everyday vocabulary items which are suitable for pediatric assessment. Children were asked to identify the target word by pointing to the corresponding picture. The authors showed that the picture-based response format improved the cooperation and response reliability and consistency among children during testing. The study highlighted the importance of using native-language and child-friendly speech materials for reliable pediatric speech audiometry assessment.

Another important pediatric speech perception material developed in Malayalam is the Lexical Neighbourhood Test for Children in Malayalam (LNT-M*)* (Nayana, 2018). The material was developed based on lexical familiarity and phonological similarity between Malayalam words. The study mainly focused on evaluating speech perception abilities in children using age-appropriate and linguistically familiar stimuli. The developed test highlighted the importance of lexical characteristics and native-language familiarity during pediatric speech perception assessment.

Although there is availability of a few conventional speech audiometry materials in Malayalam, the number of standardized pediatric speech perception materials remains limited. Most of the available materials mainly focus on general speech perception assessment and are not specifically designed to evaluate high-frequency speech perception abilities in both children and adults. There is limited availability of Malayalam high-frequency word lists for children that specifically highlight speech sounds carrying important high-frequency information. Since high-frequency consonants contribute significantly to speech intelligibility and are commonly affected in individuals with high-frequency hearing loss, the development of age-appropriate and linguistically familiar high-frequency speech materials becomes clinically important. Hence, the present study aimed to develop and standardize a Malayalam high-frequency speech identification test for children by selecting familiar words with dominant high-frequency spectral characteristics in pediatric speech audiometry assessment.

2.5 Speech Perception in Noise in Children

Speech perception in noise is an important part of audiological assessment, especially when assessment is done in children, as the environment they majorly get exposed to such as classrooms and playgrounds often contain lot of background noise. Children generally experience greater difficulty than adults in understanding speech in noisy conditions because their auditory system and language abilities are still developing (Nittrouer & Boothroyd, 1990).

These difficulties are even seen in children with normal hearing sensitivity that they may show reduced speech understanding in noisy listening conditions.

Research has shown that children require a higher SNR than adults to achieve similar speech recognition performance. Elliott (1979) reported that younger children need higher SNRs for accurate speech understanding in noisy environments due to immature auditory processing abilities. Similarly, Fallon et al. (2000) showed that performance of school-aged children were significantly poorer than adults in speech-in-noise tasks, especially at lower SNRs. The authors suggested that the main reason for such findings were lack of maturation of auditory closure abilities and linguistic processing which contributes to the improvement of speech perception in noise and these abilities will improve with increasing age and will be able to perform once these are fully matured.

Crandell and Smaldino (2000) highlighted that classroom noise can negatively affect speech understanding, academic performance, and attention in children. The study showed that children are more vulnerable to the adverse effects of noise and reverberation because they depend heavily on auditory cues for language understanding, learning and for active classroom participation. The difficulties experienced by children with hearing loss are even greater in noisy environments due to reduced audibility and reduced access to high-frequency speech cues.

In children with hearing impairment, speech perception in noise becomes more difficult because background noise masks important consonant cues that are very essential for speech perception. Studies have shown that children with hearing loss require substantially better listening conditions than their normal-hearing children to achieve comparable speech recognition performance (McCreery et al., 2012). Difficulties in speech understanding in noise can affect communication, language development, and educational performance in children.

2.6 Factors Affecting Speech Audiometry in Children

Speech perception testing in children is affected by several auditory, linguistic, cognitive, and environmental factors. Unlike adults, children are still developing their auditory system, speech and language abilities, attention skills, and cognitive processing. Because of this ongoing process of development, children may respond differently while during speech audiometry tasks, mainly in difficult listening situations such as background noise. Therefore, it is important to consider these factors while developing and administering pediatric speech perception tests (Gelfand, 2016).

2.6.1 Age and Auditory Maturation

Age is one of the major factors influencing speech perception abilities in children. Younger children generally perform poorer than older children and adults, particularly in noisy listening conditions. This happens because the central auditory nervous system and higher auditory processing abilities are in constant maturation throughout childhood. Abilities such as auditory attention, auditory closure, temporal processing, and linguistic processing slowly improve with age. As children get older, their ability to identify speech in noisy or difficulty listening conditions also improves along with it. Studies have shown that children require more better listening conditions than adults for good speech understanding, and adult-like speech perception abilities may not be fully achieved until the reach adolescence (Elliott, 1979; Nittrouer & Boothroyd, 1990).

2.6.2 *Hearing Sensitivity and Audibility of Speech Cues*

Hearing sensitivity plays an important role in speech perception performance in both adults as well as children. Children with hearing loss may not receive enough speech cues that are very important for speech perception, mainly high-frequency consonant such as /s/, /f/, /ʃ/, and /t/ are easily affected. These consonants mainly carry important information for speech clarity and intelligibility. Even mild or high-frequency hearing loss can have huge negative impact on speech identification abilities in children. Children with hearing impairment often require higher SNR than normal-hearing children for better speech recognition (McCreery et al., 2012).

2.6.3 ***Linguistic Familiarity and Vocabulary Knowledge***

The familiarity of speech material has huge influence on speech perception performance in children. Children can identify familiar and commonly used words more accurately than unfamiliar words. If test words are not from the child's vocabulary level, the scores obtained may not truly reflect the child's auditory abilities. Therefore, pediatric speech perception materials should only include age appropriate and linguistically familiar words. Owens (1961) reported that word familiarity has a strong influence on speech audiometry performance. Similarly, Gelfand (2016) highlighted that speech materials used for assessment in children should be selected in such a way that familiar words are only included in it, this is done to minimize the effect of vocabulary differences in test materials.

2.6.4 ***Cognitive and Attention Factors***

Speech perception testing in children is also negatively affected by cognitive abilities such as attention, memory and understanding of the task. Younger children usually have shorter attention spans than elder children and may become distracted very easily during the testing. In some cases, inconsistent responses may occur because the child was not able to understand the instructions or loses concentration during the task. Memory and processing abilities also affect how accurately children can repeat or identify speech stimuli. Therefore, pediatric speech tests are generally designed with simple instructions, shorter test durations, and engaging response methods to maintain constant interest and cooperation throughout testing by the child (Jerger et al., 1983).

2.6.5 *Effect of Background Noise*

Background noise has a greater negative effect on speech perception in children than in adults. Noise masks important acoustic cues that is required for speech understanding, particularly high-frequency consonant information. Children require a higher SNR compared to adults to recognize speech accurately in noisy environments. This difficulty becomes more noticeable in children with hearing loss because their access to speech cues is reduced compared to normal hearing children. Several studies have shown that speech perception in noise continues to improve throughout childhood, and younger children are easily affected in noisy environments (Elliott, 1979; McCreery et al., 2012).

2.6.6 *Native Language and Language Exposure*

Speech perception scores are usually better when test materials are presented in the child's native language. Differences in phonology, vocabulary familiarity, and linguistic structure between languages can affect test results. Children may perform very poorly with unfamiliar language materials even though hearing sensitivity is normal. Therefore, speech audiometry materials developed in the native language give a more reliable view of the child's hearing abilities. Studies have reported that linguistic complexity and second-language exposure can significantly affect speech recognition performance, especially in noisy conditions (Warzybok et al., 2015).

2.6.7 ***Type of Response Format***

The type of response required during testing can also influence pediatric speech perception performance. Open-set tasks require the child to repeat the heard word without any responses to choose from and this type of response format are generally more difficult because they require high knowledge in language and memory skills. In case of closed-set tasks, it provides limited number of response alternatives such as pictures or written choices, making the task easier for children. Because closed-set methods require less cognitive and linguistic load, they are commonly used in pediatric audiology assessment. Picture identification tests are especially useful for younger children and those with limited expressive language (Trimmis et al., 2023).

In conclusion, the review of literature highlights the importance of speech perception assessment in children and highlights the need for language-specific high-frequency speech identification materials for reliable and accurate pediatric audiological evaluation. Previous studies across various Indian languages have showed that high-frequency word lists are clinically useful in identifying speech perception difficulties associated with high-frequency hearing loss and giving a better understanding about the real-world difficulty faced by the person. The reviewed literature also indicates that factors such as age, listening condition, linguistic familiarity, response format, and auditory maturation significantly influence speech identification performance in children. However, there remains a limited availability of standardized high-frequency speech identification materials in Malayalam for pediatric assessment.

Chapter 3

Methods

The following methodology was adopted to address the objectives of the study. The study was carried out in two phases:

Phase 1: Development of high-frequency word lists for children.

Phase 2: Standardization of the developed test material.

3.1 Phase 1: Development of High-frequency Word lists for Children

The following steps were followed for the development of the high-frequency word lists:

- Selection of high-frequency words for children.
- Assessment of familiarity with the selected high-frequency words.
- Acoustic validation of the high frequency words.
- Construction of word subtests.

3.1.1. Selection of high-frequency words for children

Bisyllabic and trisyllabic words with high redundancy were chosen for the development of the word list. The words were compiled from a variety of sources, including dictionaries, children's magazines, school textbooks, and storybooks. Words having syllables /s/, /ʃ/, /tʃ/, /t͡ʃʰ/, /k/, and /t/ were preferred phonemes. These phonemes were preferred because they contain spectral energy above 1000 Hz (Stelmachowicz et al., 2004) Words containing the vowels /i/ and /e/ were preferred because the F2 and F3 frequencies of these vowels are higher compared to those of other vowels (Kent & Vorperian, 2018). Totally, 426 bisyllabic and trisyllabic words were initially collected from several sources stated.

3.1.2 Assessment of familiarity with the selected high-frequency words

To establish familiarity, the selected words were verified to be commonly used and familiar to children who are native speakers of Malayalam. The familiarity of the test items was evaluated on three children who were native Malayalam speakers and studying in Malayalam-medium schools. They were asked to tell the meaning of the selected words. A printed version of the words, along with instructions for rating familiarity, was also provided to the parents or caretaker, and each parent or caretaker was instructed to tick the most appropriate column with respect to the child's familiarity to the respective word. A three-point rating scale consisting of very familiar, familiar, and not familiar was used to assess word familiarity. The categories were defined as follows:

- **Very familiar:** Words that were commonly used by the participants.
- **Familiar:** Words that were used occasionally but were familiar to the participants.
- **Not familiar:** Words that were not used by the participants.

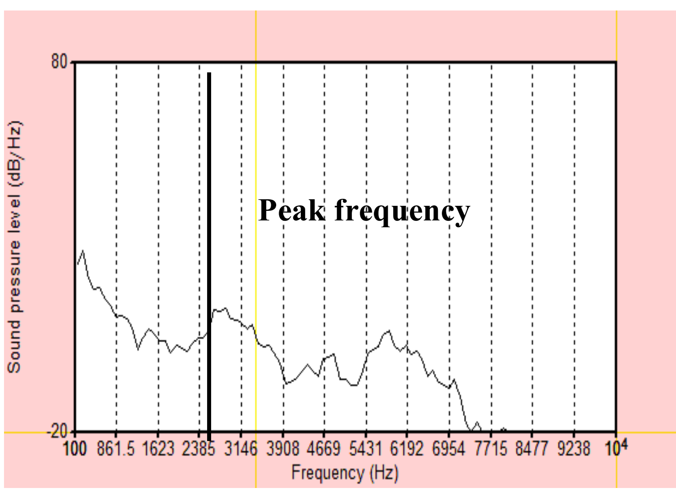
Of the 426 words evaluated, 262 were rated by parents as "very familiar," and the children knew the meanings of these words. These words were subsequently selected for the construction of the word list.

3.1.3 Acoustic validation of the familiar words

The familiar words were acoustically validated using long-term average speech spectrum (LTASS) and spectral centroid analysis. LTASS was used to ensure that the spectral information of familiar words is predominantly in the higher frequencies. It was necessary as the spectral information of the phonemes /s/,/ʃ/, /tʃ/,/t͡ʃ^h/,/k/, and /t/ could differ depending on the context, and hence the so-called high-frequency word may not have high-frequency spectral information. For the estimation of LTASS, the words were recorded by an adult female, who was a native Malayalam speaker. The words were recorded in a sound-treated room using Adobe Audition *(version 2025)*. The recording was done at a 44.1 KHz sampling rate and 16-bit quantization, and the samples were stored on a computer. LTASS was derived using PRAAT software by feeding the audio samples individually, and the spectral information was derived manually. The peak frequency of the spectrum with the highest energy concentration was considered as the target parameter. Among the selected words, 186 out of 262 exhibited maximum energy above 2000 Hz. For the present study, a cutoff criterion of 2000 Hz was adopted to enhance sensitivity to high-frequency hearing loss as conventional speech audiometry testing reflects low to mid frequency deficit not high frequency deficit (Naqvi & Sutton, 2026). The spectrum derived from the LTASS for a representative word is shown in Figure 3.1.

Fig 3.1

Spectrum derived from LTASS for a representative word.



The 186 words that were selected based on LTASS results were further analyzed using spectral centroid analysis to ensure precise selection. The spectral centroid is a measure that represents the “centre of gravity” of the frequency spectrum of a sound signal. It indicates where the majority of acoustic energy is concentrated, and higher spectral centroid values correspond to signals with greater high-frequency content (Peeters, 2004). This analysis was carried out using *MATLAB R2025b*. To do this, each recorded audio file of the word was run through a MATLAB script that obtains spectral centroid values. The centroid was calculated as the weighted mean of the frequencies in the signal, with weights proportional to the amplitudes of each frequency component. Of these, 152 words exhibited a central frequency above 2000 Hz. These words were subsequently categorized into different frequency ranges: 2.0–2.5 kHz, 2.5–3.0 kHz, 3.0–3.5 kHz, and 3.5–4.0 kHz. From this pool of 152 words, 150 were randomly selected for the construction of the high-frequency word list.

3.1.4 Construction of word subsets

Following spectral centroid analysis, the 150 selected words were categorized into 100 bisyllabic words and 50 trisyllabic words. From these words two full lists of bisyllabic words and one full list of trisyllabic words were constructed. Each of the lists was further divided into four half lists of bisyllabic and two half lists of trisyllabic, each containing 25 words. During this process, randomization was carried out while maintaining an equal distribution of high-frequency phonemic components across all half-lists. The bisyllabic and trisyllabic word lists are given in the Appendix I, II and III.

The developed test material was recorded in a sound-treated room (Frank, 2000). Five native speakers of Malayalam were selected for the recording of test words. Initially, a small set of random words (five words) from the developed list was recorded from each speaker using a laptop (Asus Tuf F15, Intel Core i5 10th Gen processor) in Adobe Audition 2025 software, with a Dual Diaphragm Condenser Microphone B.2 Pro and MOTU M2. These sample recordings were then evaluated by five Speech-Language Pathologists (SLPs)/Audiologists who were native

Malayalam speakers based on clarity, pronunciation, and fluency. Based on this evaluation, one speaker who demonstrated the best overall performance was selected for the final recording. Subsequently, the complete set of test words was recorded using the same speaker under identical recording conditions.

During recording, the microphone was positioned 5 inches away from the speaker, and the VU meter was monitored to maintain optimum recording levels. The speaker was instructed to produce the words at a normal pitch and with consistent loudness throughout the recording. The recordings were made in a mono channel using a sampling rate of 44.1 kHz and 16-bit quantization. The intensity of each word was normalized to −3 dB, following which each word was saved as a .wav file. The words were then arranged as continuous lists with an interstimulus interval of 4 seconds to provide sufficient response time for the participants, based on standard speech audiometry procedures (Wilson & McArdle, 2005).

3.2 Phase 2: Standardization of the Test Material

The developed test material was standardized using the following criteria and procedure:

3.2.1 Participants

The developed test material was standardized by obtaining speech identification scores (SIS) from 100 children in the age range of 7 years to 11 years 11 months who were native speakers of Malayalam. Prior to the data collection, permission was taken from the respective school authorities to conduct the study. The participants were stratified into five distinct age groups, each comprising of 20 children with an equal distribution of males (n = 10) and females (n = 10). The participants were categorized into five age groups, and the mean age with standard deviation (SD) for each group was as follows:

- 7 years to 7 years 11 months (Mean=7.42±0.23 years)
- 8 years to 8 years 11 months (Mean=8.36±0.22 years)
- 9 years to 9 years 11 months (Mean=9.37±0.19 years)
- 10 years to 10 years 11 months (Mean=10.32±0.21years)
- 11 years to 11 years 11 months (Mean=11.47±0.18 years)

Participant sélection criteria

An initial case history was obtained from all participants to document demographic details, developmental milestones, medical and educational background, and relevant audiological history. The following criteria were considered for the inclusion of the participants:

- Bilateral normal hearing sensitivity ranges from 250 Hz to 8000 Hz for air conduction and 250 Hz to 4000 Hz for bone conduction as obtained by a modified version of the Hughson and Westlake procedure (Carhart & Jerger, 1959).
- Bilateral A-type tympanogram and acoustic reflexes (ipsilateral & contralateral reflex) present in both ears to ensure normal middle ear functioning.
- Good/average educational performance as per the teacher's report.
- Pass in screening checklist for auditory processing (SCAP) (Yathiraj & Mascarenhas, 2002).

Further, participants included in the study had no history of hearing loss, ear disease, trauma, ototoxic drug intake, ear surgery, or neurological problems. It was also ensured that none of the participants had any current illness that could affect their hearing abilities or overall test performance.

3.2.2 Test environment and ethical guidelines

All evaluations were carried out in a school, single room situation. The testing room was located on the top floor of the building and was situated away from major sources of external noise such as roads and playground areas, in order to minimize environmental noise. The environmental noise was measured using Samsung S25 Ultra mobile with Sound Meter application developed and published by rootApps. The measured noise levels ranged between approximately 40 to 45 dB SPL during the testing period (Frank, 2000). Consistent environmental conditions were maintained throughout the evaluation to ensure the reliability of the results.

Each participant was given a consent form to be signed by a parent or caregiver and submitted on the day of data collection. Ethical approval was obtained from the institutional ethics committee of All India Institute of Speech and Hearing, Mysore prior to data collection (SH/IRB/M.4/AUD.09/2025-26) (Appendix IV).

3.2.3. ***Instrumentation***

- A calibrated single-channel AD226 audiometer (Interacoustics, Middlefart, Denmark) coupled with acoustically matched HDA-200 Circum-aural headphones (Sennheiser GmbH &Co. KG, Wedemark, Germany) and B-71 bone vibrator (RadioEar, New Eagle, PA, USA) were utilized to estimate pure tone thresholds.
- A calibrated Titan IMP440 screening tympanometer (Interacoustics, Middlefart, Denmark) was used to perform tympanometry and acoustic reflexes.

- An ASUS TUF F15 laptop (ASUS, Taipei, Taiwan) calibrated with Sennheiser HDA-200 headphones using a KEMAR manikin and Windows Media Player software were used to present the developed test material.

3.2.4 Procedure

Initially, screening for auditory processing was carried out using the SCAP(Yathiraj & Mascarenhas, 2002), which was provided one day prior to the class teachers along with instructions for its completion. Children who passed the screening were further evaluated through audiological assessments, including pure-tone audiometry and immittance audiometry. Pure-tone audiometry was performed using a calibrated screening audiometer in a classroom, with air conduction thresholds measured at octave frequencies from 250 Hz to 8000 Hz using the modified Hughson-Westlake procedure (Carhart & Jerger, 1959). Pure-tone averages were calculated at 500 Hz, 1 kHz, 2 kHz, and 4 kHz. Immittance audiometry was performed using a 226 Hz probe tone, and tympanograms were classified according to the Jerger (1970) classification system. Only children with Type A tympanograms, indicating normal middle ear function, were included in the study. Only those children with PTA ≤ 15 dB HL in both ears (after subjective claiberation) and normal tympanometry findings (American Speech-Language-Hearing Association, 2005; Carhart & Jerger, 1959) were selected for the administration of the word list.

The high-frequency word identification list developed in Phase 1 was played through the laptop at the calibrated volume, delivering the stimulus through Sennheiser HDA-200 headphones. The output of the headphones was calibrated before the testing, using a KEMAR manikin to deliver an output of 65 dBSPL (Guthrie & Mackersie, 2009). All participants were tested monaurally using the developed test material, with the right ear assessed in 50% of the participants and the left ear assessed in the remaining 50%. Further, the participants were initially tested under noise condition, and the quiet condition scores were obtained from the same participants after an interval of one week. Open-set oral responses were obtained from the participants, and all responses were scored with the assistance of a native Malayalam interpreter throughout data collection. Responses were marked as correct only when they matched the target stimulus in pronunciation and lexical form. Prior to word recognition testing, instructions were provided to each participant in Malayalam.

"You will hear lists of Malayalam words several times at a specific level. The silent gap between each word will be about 4 seconds. Please listen carefully and repeat out loud the word that you hear. If you are unsure of a word, you are encouraged to guess. If you have no guess, say *I do not know,* or wait silently for the next word. Do you have any questions?"

3.2.6 *Scoring*

After assessment of the Malayalam High Frequency speech identification test for children, the responses were scored as follows:

- Each correct response was given a score of 1
- Each incorrect response was given a score of 0

The raw scores were converted to a percentage as follows:

$$\textbf{Total score (\%)} = \frac{\textbf{Total number of correct responses x 100}}{\textbf{Total number of words presented}}$$

3.2.7 Statistical Analysis

The statistical analysis was carried out using IBM SPSS Statistics (version 26) software. Descriptive statistics were used to determine the mean and SD of the study variables. Tests of normality were performed using the Shapiro–Wilk test. Non-parametric tests were used as the data were not normally distributed. Mann–Whitney U test and Kruskal–Wallis test was used to compare the scores between genders and to compare the scores across different age groups respectively. Friedman test was used for within-group or list wise comparisons, and Wilcoxon signed-rank test was used to compare the performance between quiet and noise conditions.

Chapter 4

Results

The Malayalam high-frequency word lists for speech identification in children was developed through a systematic multi-phase process involving word selection, assessment of familiarity, acoustic validation using Long-Term Average Speech Spectrum (LTASS) and spectral centroid analysis, and the construction of balanced word subtests. This was followed by the development of normative data in children across different age groups. The results of each phase are provided below:

4.1 Development of the high frequency word lists for children.

4.2 Development of the normative for the Malayalam high frequency wordlist for children.

4.3 Comparison of the speech identification scores (SIS) obtained across each lists and age to check the equality of the lists developed.

4.1 Development of the high frequency word lists for children.

4.1.1 *Selection of the words and their familiarity*

Initially, a total of 426 words were collected from various sources, such as children's story books, corpus data, and textbooks developed for 1st and 2nd standard students. This list contained both bisyllabic and trisyllabic words. Familiarity rating was done for these words using five native speakers of Malayalam and children studying in Malayalam medium school aged between 7 years to 8 years with help of their parents. Familiarity check was done through virtual mode, and parents were given instruction about the testing and procedure. A score sheet was provided prior to the familiarity testing including the wordlist. The final results of the tests were sent via mail. The result of the familiarity check showed that 262 words out of 426 words were rated as most familiar and were further considered for acoustic validation.

4.1.2 *Acoustic validation of high-frequency words*

The familiar words obtained after the familiarity assessment were subjected to LTASS analysis to identify words containing higher-frequency spectral energy. LTASS analysis was done for the 262 words shortlisted after the familiarity check to analyse and validate the spectral information. Peak frequency measure made by visual inspection of the spectra was considered as the inclusion criterion for selecting the word. LTASS analysis results revealed that 186 words out of 262 words had energy concentration at and above 2 kHz. These 186 words were considered for further analysis using the spectral centroid.

The shortlisted 186 words were then analysed with the spectral centroid measure, which were selected after the LTASS assessment, to check the center of gravity of the energy concentration in each word. The words which had a spectral centroid above 2 kHz were selected for the construction of the word list. Out of 186 words analysed, 152 words had a spectral centroid above 2kHz which were selected to construct the final word lists. The distribution of selected words across spectral centroid frequency ranges based on spectral centroid analysis is given in Table 4.1. From Table 4.1, it can be noted that 152 words had spectral energy concentration above 2 kHz. The majority of the word’s spectral energy falls between 2 kHz and 2.5 kHz. Out of these 152 words, two words with the lowest spectral centroid value were removed and a total of 150 words were used to construct the final high-frequency word lists.

Table 4.1

Distribution of selected words across spectral centroid frequency ranges based on spectral centroid analysis

Spectral Centroid Values (kHz)	Number of words
2 kHz to 2.5 kHz	65
2.5 kHz to 3.0 kHz	42
3.0 kHz to 3.5 kHz	27
3.5 kHz to 4.0 kHz	12
Above 4 kHz	6
Total	**152**

4.1.3 Construction of the word subtests

A total of 150 words met the spectral centroid criterion of above 2 kHz, comprising 100 bisyllabic and 50 trisyllabic words. Based on their spectral centroid values, the words were grouped into different frequency ranges (e.g., 2–2.5 kHz, 2.5–3 kHz, and above) to facilitate balanced list construction and reduce inter-list variability. The bisyllabic words were divided into two lists of 50 words each, while the trisyllabic words formed one list of 50 words. These three lists were further subdivided into six half-lists containing 25 words each, including four bisyllabic and two trisyllabic half-lists. During list construction, care was taken to include an approximately equal number of words from each spectral centroid range in every half-list to maintain comparable acoustic energy distribution and perceptual equivalence across the lists.

Descriptive statistics were computed to obtain the mean and standard deviation (SD) of the spectral centroid values for the half-lists constructed from the finalized 150 words. Table 4.2 presents the mean and SD of the spectral centroid values for each half-list. Further, a one-way analysis of variance (ANOVA) was carried out to determine whether significant differences existed in the spectral centroid values across the six half-lists. The results revealed no significant difference in the spectral centroid among the lists [$F(5,144) = 0.290$, $p > 0.05$], indicating that all half-lists had comparable spectral energy distribution.

Table 4.2

Mean and SD of spectral centroid values across the constructed half-lists

List	Number of words	Mean Spectral centroid	SD
List 1: Half-list 1	25	2656.08	575.26
List 1: Half-list 2	25	2649.33	541.82
List 2: Half-list 1	25	2704.95	614.07
List 2: Half-list 2	25	2676.04	587.63
List 3: Half-list 1	25	2804.75	665.59
List 3: Half-list 2	25	2773.92	603.56
Total	**150**	**2710.84**	**592.01**

4.2 Development of the Normative for the Malayalam High Frequency Wordlist for Children

Normative data for the developed test material were established by administering the six half-lists to 100 normal-hearing children (native speakers of Malayalam) in two listening conditions: quiet and +2dB SNR. Initially, a pilot study was carried out on three Malayalam- native speaking children aged between 7 years and 7 years 11 months who were studying in Malayalam medium schools to find the appropriate signal-to-noise ratio (SNR) at which 50% score is obtained for administering the speech identification test under noise conditions. Different SNRs, namely −5 dB, −3 dB, 0 dB, and +3 dB, were evaluated initially. The findings revealed that the 0 dB SNR resulted in speech identification scores below 50%, indicating a high level of difficulty, whereas the +3 dB SNR scores were above 65%, indicating relatively easier identification. Therefore, an intermediate SNR of +2 dB was evaluated later, which produced scores between 50% and 65%. Since this SNR provided the required level of difficulty for assessing speech identification performance in noise, +2 dB SNR was selected for the main study and subsequent data collection.

Normative data were established for the developed test using 100 normal-hearing children (50 males and 50 females) between the ages of 7 years 0 months and 11 years 11 months. The participants were divided into five age groups, with each group comprising 10 males and 10 females. The mean and SD was estimated for the speech identification scores (SIS) obtained across all the six lists in both quiet and noise conditions and the results are given in the Table 4.3 and Table 4.4 respectively.

Table 4.3

Mean and SD of SIS scores obtained under noise condition across age groups.

Age Group	Statistic	L1:HF1	L1:HF2	L2:HF1	L2:HF2	L3:HF1	L3:HF2
7–7.11 Years	Mean	53.60	54.80	55.80	53.60	55.00	54.40
	SD	2.39	2.93	3.99	2.39	3.15	2.72
8–8.11 Years	Mean	56.60	56.80	56.60	55.60	54.40	55.00
	SD	2.35	3.33	3.25	3.15	2.72	3.15
9–9.11 Years	Mean	55.00	56.60	55.60	55.60	55.60	56.00
	SD	3.15	2.68	3.15	3.65	3.15	2.25
10–10.11 Years	Mean	55.80	57.00	56.40	57.20	55.60	55.40
	SD	3.55	3.15	2.87	2.63	3.41	2.98
11–11.11 Years	Mean	57.40	57.20	55.40	55.80	56.40	55.80
	SD	3.73	4.32	3.25	3.30	3.65	3.30

Note: L1= List 1; L2 = List 2; L3 = List 3 ; HF1 = Half-list 1; HF2 = Half-list 2;

Table 4.4

Mean and SD of SIS scores obtained under quiet condition across age groups.

Age Group	Statistic	L1:HF1	L1:HF2	L2:HF1	L2:HF2	L3:HF1	L3:HF2
7–7.11 Years	Mean	94.45	94.20	94.05	94.05	94.25	94.05
	SD	2.39	2.93	3.99	2.39	3.15	2.72
8–8.11 Years	Mean	98.20	96.40	95.80	95.80	96.65	96.65
	SD	2.35	3.33	3.25	3.15	2.72	3.15
9–9.11 Years	Mean	100.00	100.00	100.00	100.00	100.00	100.00
	SD	0.00	0.00	0.00	0.00	0.00	0.00
10–10.11 Years	Mean	100.00	100.00	100.00	100.00	100.00	100.00
	SD	0.00	0.00	0.00	0.00	0.00	0.00
11–11.11 Years	Mean	100.00	100.00	100.00	100.00	100.00	100.00
	SD	0.00	0.00	0.00	0.00	0.00	0.00

Note: L1 = List 1; L2 = List 2; L3 = List 3; HF1 = Half-list 1; HF2 = Half-list 2

4.2.1 Comparison of SIS scores between Genders

Table 4.5 shows the gender-wise distribution of SIS scores under quiet and noise conditions. The table indicates that the mean SIS scores were comparable between males and females across all age groups. Further, a Mann-Whitney U test was conducted to compare scores between males and females across different age groups under both noise and quiet conditions. The analysis of the data revealed that there was no statistically significant difference in SIS scores between males and females across both noise and quiet conditions. This finding shows that gender doesn't influence speech performance in children. The results of Mann Whitney U test for gender differences in SIS are depicted in Table 4.6 and Table 4.7.

Table 4.5

Gender wise Mean and SD of SIS scores under noise and quiet conditions across age groups

Age Group	Gender	SIS in Noise		SIS in Quiet	
		Mean	SD	Mean	SD
7–7.11 Years	Male	54.00	2.83	94.40	2.07
	Female	53.20	1.93	94.50	2.17
8–8.11 Years	Male	56.40	2.70	98.00	2.11
	Female	55.20	1.89	97.80	2.07
9–9.11 Years	Male	55.60	2.53	100.00	0.00
	Female	55.40	3.27	100.00	0.00
10–10.11 Years	Male	56.80	2.95	100.00	0.00
	Female	55.60	4.22	100.00	0.00
11–11.11 Years	Male	56.40	3.50	100.00	0.00
	Female	55.80	3.29	100.00	0.00

Note: L1 = List 1; L2 = List 2; L3 = List 3; HF1 = Half-list 1; HF2 = Half-list 2

Table 4.6

Mann-Whitney U test results for gender wise comparison of scores in noise condition

Age Group	Statistic	L1:HF1	L1:HF2	L2:HF1	L2:HF2	L3:HF1	L3:HF2
7–7.11 Years	U-value	43.500	37.500	40.000	47.000	32.500	27.000
	p-value	0.557	0.304	0.423	0.786	0.154	0.054
8–8.11 Years	U-value	36.500	36.500	36.500	36.500	36.500	36.500
	p-value	0.226	0.226	0.226	0.226	0.226	0.226
9–9.11 Years	U-value	24.500	24.500	24.500	24.500	24.500	24.500
	p-value	0.255	0.255	0.255	0.255	0.255	0.255
10–10.11 Years	U-value	49.500	49.500	49.500	49.500	49.500	49.500
	p-value	0.968	0.968	0.968	0.968	0.968	0.968
11–11.11 Years	U-value	48.500	48.500	48.500	48.500	48.500	48.500
	p-value	0.903	0.903	0.903	0.903	0.903	0.903

Note: L1 = List 1; L2 = List 2; L3 = List 3; HF1 = Half-list 1; HF2 = Half-list 2

Table 4.7

Mann-Whitney U test results for Gender wise comparison of scores in quiet condition

Age Group	Statistic	L1:HF1	L1:HF2	L2:HF1	L2:HF2	L3:HF1	L3:HF2
7–7.11 Years	U-value	47.000	45.000	38.000	47.500	42.500	43.000
	p-value	0.796	0.661	0.306	0.831	0.522	0.551
8–8.11 Years	U-value	45.000	45.000	45.000	45.000	45.000	45.000
	p-value	0.661	0.661	0.661	0.661	0.661	0.661
9–9.11 Years	U-value	50.000	50.000	50.000	50.000	50.000	50.000
	p-value	1.000	1.000	1.000	1.000	1.000	1.000
10–10.11 Years	U-value	50.000	50.000	50.000	50.000	50.000	50.000
	p-value	1.000	1.000	1.000	1.000	1.000	1.000
11–11.11 Years	U-value	50.000	50.000	50.000	50.000	50.000	50.000
	p-value	1.000	1.000	1.000	1.000	1.000	1.000

Note: L1 = List 1; L2 = List 2; L3 = List 3; HF1 = Half-list 1; HF2 = Half-list 2

4.2.2 *Comparison of SIS across age groups*

The data obtained were compared across the five age groups under quiet and noise conditions to determine whether age had a significant influence on SIS performance. A Kruskal-Wallis test was performed to compare the scores across different age groups, as the data were not normally distributed. Results showed the main effect of age on SIS scores in noise for L1:HF1 and L2:HF2. The effect of age was not significant for all the other lists, as shown in Table 4.8. Post hoc pairwise comparisons with the adjusted Bonforreni corrections were performed following significant Kruskal–Wallis results, and the results are depicted in Table 4.9. From Table 4.9, it can be noted that SIS in noise significantly differed between age group 1 (7-7.11years) and age group 2 (8-8.11years), and between age group 1 (7-7.11years) and age group 5 (11-11.11years) for L1:HF1 scores. For L2:HF2scores, significant differences in SIS were observed between age group 1 (7-7.11years) and age group 4 (10-10.11years). These findings indicate better SIS performance in older children compared to younger children.

The Kruskal–Wallis test conducted to assess the effect of age on SIS scores in quiet revealed a significant main effect of age on SIS scores across all the lists. The results are depicted in Table 4.10. Post hoc pairwise comparisons with the Mann-Whitney U test were performed following a significant Kruskal–Wallis results, and the results are depicted in Table 4.11.

Table 4.8

Kruskal–Wallis test results for age-wise comparison of SIS scores in noise

Variable	H value	p-value	Interpretation
L1:HF1	**16.473**	**0.002**	**Significant**
L1:HF2	6.336	0.175	Not significant
L2:HF1	2.364	0.669	Not Significant
L2:HF2	**13.069**	**0.011**	**Significant**
L3:HF1	3.674	0.452	Not Significant
L3:HF2	4.462	0.346	Not Significant

Note: L1 = List 1; L2 = List 2; L3 = List 3; HF1 = Half-list 1; HF2 = Half-list 2

Table 4.9

Post hoc pairwise comparisons between age groups for SIS in noise

Variable	Significant Age Groups	Adjusted p-value
L1:HF1	7-7.11 vs 8-8.11years	0.012
L1:HF1	7-7.11 vs 11-11.11years	0.004
L2:HF4	7–7.11 vs 10–10.11years	0.003

Note: L1 = List 1; L2 = List 2; L3 = List 3; HF1 = Half-list 1; HF2 = Half-list 2

Table 4.10

Kruskal–Wallis test results for age-wise comparison of SIS scores in quiet

Variable	H value	p-value	interpretation
L1:HF1	76.750	<0.001	Significant
L1:HF2	76.149	<0.001	Significant
L2:HF1	76.830	<0.001	Significant
L2:HF2	76.830	<0.001	Significant
L3:HF1	78.943	<0.001	Significant
L3:HF2	79.276	<0.001	Significant

Note: L1 = List 1; L2 = List 2; L3 = List 3; HF1 = Half-list 1; HF2 = Half-list 2

Table 4.11

Post hoc pairwise comparisons between age groups for SIS in quiet

Variable	Significant Age Group Comparisons	Adjusted *p*-value
L1:HF1	7–7.11 vs 8–8.11 Years	<0.001
	7–7.11 vs 9–9.11 Years	<0.001
	7–7.11 vs 10–10.11 Years	<0.001
	7–7.11 vs 11–11.11 Years	<0.001
	8–8.11 vs 9–9.11 Years	0.042
	8–8.11 vs 10–10.11 Years	0.042
	8–8.11 vs 11–11.11 Years	0.042
L1:HF2, L2:HF1, L2:HF2, L3:HF1, L3:HF2	7–7.11 vs 9–9.11 Years	<0.001
	7–7.11 vs 10–10.11 Years	<0.001
	7–7.11 vs 11–11.11 Years	<0.001
	8–8.11 vs 9–9.11 Years	<0.001
	8–8.11 vs 10–10.11 Years	<0.001
	8–8.11 vs 11–11.11 Years	<0.001

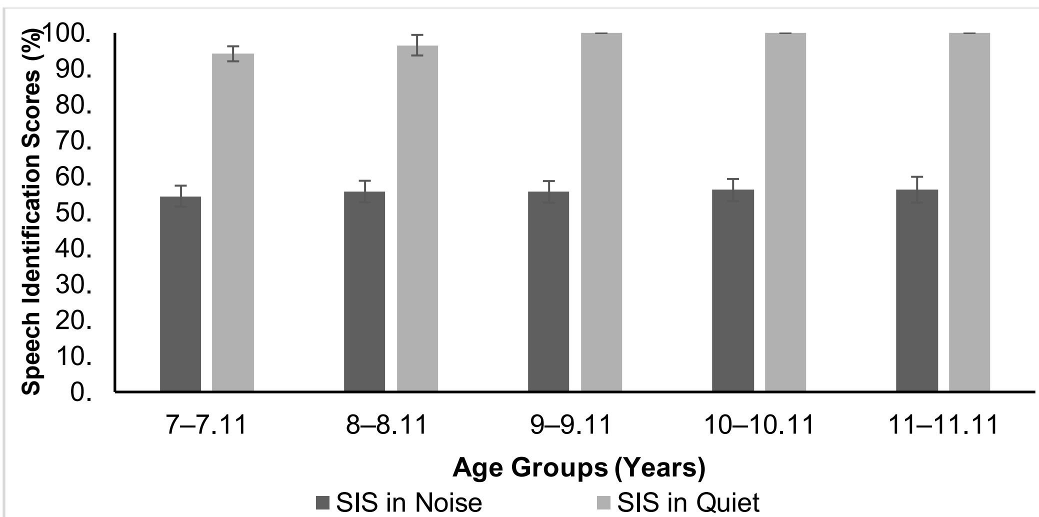
Note: L1 = List 1; L2 = List 2; L3 = List 3; HF1 = Half-list 1; HF2 = Half-list 2

4.2.3 *Comparison of SIS across different listening condition*

Figure 4.1 shows the mean SIS scores along with SD across the age groups under both noise and quiet conditions. It can be noted that higher mean SIS scores were observed under quiet conditions than under noise conditions for all the lists. In quiet conditions, children in the older age groups showed near-ceiling performance across all the lists.

Figure 4.1

Bar graph representing the mean and SD of SIS obtained under noise and quiet conditions across age groups.



The Wilcoxon signed-rank test was performed to compare SIS scores obtained under quiet and noise conditions across all the lists, as the data were not normally distributed. Results revealed a significant difference in SIS scores between quiet and noise conditions for all the lists developed. The results are depicted in Table 4.12. Higher SIS scores were consistently observed under quiet condition compared to noise condition across all the lists, indicating that the presence of noise adversely affected speech identification performance in children.

Table 4.12

Wilcoxon Signed-Rank Test results for the Comparison of SIS Between Quiet and Noise Conditions

Variable	Z value	p-value	Interpretation
L1:HF1	8.790	<0.001	Significant
L1:HF2	8.784	<0.001	Significant
L2:HF1	8.760	<0.001	Significant
L2:HF2	8.779	<0.001	Significant
L3:HF1	8.770	<0.001	Significant
L3:HF2	8.825	<0.001	Significant

Note: L1 = List 1; L2 = List 2; L3 = List 3; HF1 = Half-list 1; HF2 = Half-list 2

4.3 Comparison of the SIS obtained across each lists to check the equality of the lists developed

To verify whether any significant difference exists in the SIS across obtained across the six lists, a Friedman test was done. This was done to compare the SIS scores across the lists within each age group, as the data were related and not normally distributed. The results of the analysis are presented in Table 4.13 and Table 4.14. From the Table 4.13 it can be noted no statistically significant difference was observed in the SIS across the lists under the noise condition for any of the age groups, indicating equivalence among the developed lists in noise. Further, from Table 4.14 we can observe that no statistically significant difference was observed across the lists under the quiet condition for the age groups 7–7.11 years, 9–9.11 years, 10–10.11 years, and 11–11.11 years. However, a statistically significant difference was observed for the age group 8–8.11 years ($p < 0.05$). Post hoc pairwise comparisons following the significant Friedman test were performed using Bonferroni-adjusted comparisons, and the results are depicted in Table 4.15. From Table 4.15, it can be noted that none of the pairwise comparisons between the lists under the quiet condition reached statistical significance after

Bonferroni correction (adjusted $p > 0.05$). Although the overall Friedman test revealed a significant difference in SIS scores for the 8–8.11 years age group, the pairwise comparisons did not demonstrate significant differences between any specific list combinations. These findings suggest that the overall variation observed across lists was not attributable to differences between individual list pairs.

Table 4.13

Friedman test results for the comparison of SIS across lists under the noise condition

Age group	χ^2 value	p-value
7–7.11 Years	6.279	0.280
8–8.11 Years	9.373	0.095
9–9.11 Years	3.917	0.561
10–10.11 Years	7.324	0.198
11–11.11 Years	3.473	0.628

Table 4.14

Friedman test results for the comparison of SIS across lists under the quiet condition

Age group	χ^2 value	p-value	interpretation
7–7.11 Years	0.602	0.988	Non-significant
8–8.11 Years	**22.778**	**<0.001**	**Significant**
9–9.11 Years	0.000	1.000	Non-significant
10–10.11 Years	0.000	1.000	Non-significant
11–11.11 Years	0.000	1.000	Non-significant

Table 4.15

Post hoc pairwise comparisons of SIS between lists under quiet condition for the age group 8-8.11 years.

Variable	Adjusted p-value	Interpretation
L2:HF1 vs L1:HF1	0.168	Non-significant
L2:HF2 vs L1:HF1	0.168	Non-significant
L2:HF1 vs L1:HF2	1.000	Non-significant
L2:HF2 vs L1:HF2	1.000	Non-significant
L2:HF1 vs L2:HF2	1.000	Non-significant
L2:HF1 vs L3:HF1	1.000	Non-significant
L2:HF1 vs L3:HF2	1.000	Non-significant
L2:HF2 vs L3:HF1	1.000	Non-significant
L2:HF2 vs L3:HF2	1.000	Non-significant
L1:HF2 vs L3:HF1	1.000	Non-significant
L1:HF2 vs L3:HF2	1.000	Non-significant
L1:HF2 vs L1:HF1	0.945	Non-significant
L3:HF1 vs L1:HF1	1.000	Non-significant
L3:HF2 vs L1:HF1	1.000	Non-significant
L3:HF1 vs L3:HF2	1.000	Non-significant

Note: L1 = List 1; L2 = List 2; L3 = List 3; HF1 = Half-list 1; HF2 = Half-list 2

Chapter 5

Discussion

The present study was done to develop and establish normative data for the Malayalam High Frequency Word List in children with normal hearing between the ages of 7 years and 11 years 11 months. The speech identification scores (SIS) were obtained from the developed material under both quiet and noise conditions across different age groups in children. This chapter discusses the results of the study and compares them with existing literature.

5.1 Development of the High frequency Word lists

The development of the word list included multiple steps. This was done to ensure that the selected words were familiar, acoustically appropriate, and equivalent across the developed half-lists. Familiarity assessment was done initially, to ensure that the words selected were commonly used and easily recognized by children within the age groups under investigation. Familiar words reduces the requirement of higher linguistic knowledge during the testing and it helps to obtain more reliable SIS (Owens & Schubert, 1977). Similar procedures have been followed in earlier speech material development studies (Chintamani, 2017; Hirsh et al., 1952).

Further acoustic validation using long term average speech spectrum (LTASS) and spectral centroid analysis was carried out to identify words with greater high frequency spectral energy. This was done to ensure that, the selected words represent high-frequency spectral energy distribution (Byrne et al., 1994). LTASS analysis helped in identifying words with energy concentration above 2 kHz initially, later spectral centroid analysis provided information regarding the centre of gravity of spectral energy distribution within the words. Selection of words with higher spectral centroid values (above 2kHz) ensured that the developed materials were mainly containing high frequency speech information. The majority of the selected words showed spectral energy concentration between 2 kHz and 2.5 kHz, which strongly indicated adequate representation of high-frequency acoustic cues within each word of the developed materials.

Further, care was taken during list construction to distribute words from different spectral centroid frequency ranges equally across all the half-lists. This was done to minimize inter-list variability and to maintain perceptual equivalency across the developed lists. Statistical analysis revealed no significant difference in spectral centroid values across the six half-lists, indicating that all lists had comparable acoustic characteristics. The absence of significant inter-list differences suggests that the developed lists were acoustically balanced and equivalent, thereby making them suitable for clinical speech identification assessment (Hirsh et al., 1952).

5.2 Development of Normative data for the Malayalam High frequency Word list for Children

5.2.1 Gender-wise Comparison of SIS Scores

The present study compared SIS between male and female children across different age groups under both quiet and noise conditions. The findings showed no significant differences in SIS scores between genders compared in both noise and quiet listening conditions. The performance of male and female children was comparable, with similar SIS obtained under both quiet and noise conditions. The findings of the present study strongly agree with previous study results reported by Prodi et al. (2019), who reported only minimal or no statistically significant differences between males and females in speech intelligibility performance. Additionally, the study also highlighted that listening performance was influenced more strongly by noise level and age rather than gender. The absence of significant performance difference across gender suggests that it does not substantially influence speech identification performance in typically developing children with normal hearing sensitivity within the age range that has been examined.

The obtained results of the present study suggest that the developed Malayalam High Frequency Word Lists can be used in both genders as it gives similar SIS performance and doesn't have performance difference across gender in the tested age range. Hence, separate normative data based on gender may not be necessary for clinical application of the developed materials.

5.2.2 Age-wise Comparison of SIS scores

The current study also compared SIS obtained across different age groups under both noise and quiet conditions. The results showed that SIS improved with increasing age. Lower SIS scores were obtained by younger children, whereas older children showed better performance under both noise and quiet listening conditions. Under noise conditions, significant age-related differences were observed. Post hoc pairwise comparisons results revealed that the performance of younger age groups differed significantly from older age groups, especially this was seen between children aged 7–7.11 years and the other higher age groups. Significant differences in SIS were observed across age groups under quiet condition for all the developed lists. Post hoc pairwise comparisons showed significant differences mainly between younger and older age groups, suggesting gradual maturation of speech perception abilities with increasing age. Older children showed near-ceiling or ceiling performance under quiet condition, indicating higher speech identification abilities in favorable listening condition.

Similar findings were observed by Neuman et al. (2010), who compared the combined effect of noise and reverberation in both children and adults. The study reported that poorer speech recognition abilities in noisy and reverberant listening conditions were seen among younger children compared to older children and adults. The poorer speech perception performance seen in younger children under noise conditions may be linked to underdeveloped central auditory nervous system functioning and reduced auditory perceptual abilities. Additionally, improvements seen in SIS scores are related to developmental changes that improve with age, such as auditory processing, linguistic abilities, auditory closure skills, and attention. This can affect the performance positively, hence higher speech perception abilities are seen (Stelmachowicz et al., 2004).

Hence, younger children experience greater difficulty; that is, they need greater signal to noise ratio (SNR) for understanding speech when presented along with noise compared to older children. Speech perception in noise requires highly efficient auditory perception abilities, which develops to better performance during childhood (Neuman et al., 2010).

5.2.3 Comparison of SIS across different listening condition

The current study compared SIS scores across different listening condition. The result revelealed that the perfomance differed significantly across different listening condition for all the list. Higher SIS scores were consistently observed under quiet condition compared to noise condition, indicating that the presence of background noise adversely affected speech identification performance in children. Children generally need a higher SNR compared to adults for successfully understanding speech, because background noise negatively affects speech perception abilities (Elliott, 1979). Elliott (1979) also reported that there is significantly better speech perception performance under quiet conditions than in noisy listening situations by children. The comparatively better performance observed under quiet conditions can be related to the absence of competing background noise and reduced auditory processing demands. In listening environments which do not have competing noise, children can depend more on acoustic speech cues without the need for high auditory closure and selective attention skills.

5.3 Comparison of SIS across Lists to determine List equivalency

Establishing list equivalency is an important step in the development of speech materials to ensure that all the developed lists are equally reliable and have similar difficulty levels. Equivalent speech lists help to ensure that differences in performance are due to the individual's speech perception ability rather than differences in the difficulty of the lists. Therefore, the equivalency of the developed lists under both quiet and noise conditions were examined using Friedman analysis. The results revealed that there were no statistically significant differences in SIS obtained across the lists developed under noise condition for any of the age groups. These findings indicate that the developed lists have similar difficulty and hence it can be considered equivalent under noise condition. Similarly, under quiet condition, there was no statistically significant differences observed across the lists for most of the age groups. Although, a significant difference was observed for the age group 8–8.11 years under quiet condition, further post hoc pairwise analysis was done which did not reveal statistically significant differences between individual list pairs following adjusted Bonferroni correction. Therefore, the developed lists may be considered relatively equivalent for clinical application.

The absence of major differences across the developed lists suggests that the procedures adopted during word selection and list construction were effective in reducing variability across different lists developed. Factors such as word familiarity, phonemic distribution, lexical characteristics, and age appropriateness are likely to have contributed to the equivalency seen across the different developed word lists. Similar methods have been done in previous speech material development studies to establish list equivalency and ensure clinical reliability of pediatric speech perception tests (Hirsh et al., 1952; Kavitha, 2002).

The near-ceiling performance observed under quiet conditions among older age groups may also have reduced variability across lists. Ceiling effects are commonly seen in pediatric speech identification assessment under favourable listening conditions when the task becomes relatively easy for older children with better auditory and linguistic abilities. Similar findings have been reported in previous speech audiometry studies, which highlighted that equivalent speech lists should give similar performance scores across listeners (Wilson, 2003).

The findings of the present study provide important insights into age-related variations in speech identification abilities under different listening conditions. The results showed better SIS performance in quiet conditions than in noise conditions across all age groups. Also, across a few age groups and listening conditions, significant differences were observed, indicating the influence of auditory maturation and listening difficulty on speech perception performance in children. The normative data hence obtained from the present study may therefore serve as a useful clinical reference for the assessment of speech identification abilities in Malayalam-speaking children.

Chapter 5

Summary and Conclusions

The present study aimed to develop Malayalam high frequency wordlists and to evaluate the influence of age, gender, and listening condition on Speech identification scores (SIS) performance in children. Six high frequency word lists consisting of four bisyllabic and two trisyllabic high-frequency Malayalam words were developed and administered to children belonging to different age groups under quiet and noise listening conditions.

The lists were developed in two phases, and initially 426 words were selected and out of which 276 words were eliminated by various analysis like familiarity check, LTASS assessment and spectral centroid measure. Later, these words were divided into half lists based on their spectral centroid values to maintain the equivalency of lists. SIS was obtained with the developed word lists in quiet and at +2dB SNR on 100 Malayalam-speaking children. Later data analysis was carried out to compare the performance across gender, age and listening conditions. Additionally, an analysis was done to find the equivalence of the lists developed. The results of the study are summarized below:

- No statistically significant gender-wise differences in SIS were observed under both quiet and noise conditions across all age groups.
- Younger children demonstrated lower SIS scores compared to older children under both listening conditions. Significant age-related differences were observed across all lists under quiet condition and for selected lists under noise condition.
- SIS scores were significantly higher under quiet condition compared to noise condition across all developed lists, indicating the negative effect of

background noise on speech perception in children.

- Friedman test analysis revealed no significant differences among the developed SIS lists under both quiet and noise conditions. Thus, the developed Malayalam high-frequency SIS lists demonstrated comparable difficulty levels and can therefore be considered equivalent for clinical application in children.

Overall, the present study successfully developed Malayalam high frequency word list suitable for assessing speech perception abilities in Malayalam speaking children. The developed lists demonstrated equivalence across listening conditions and age groups and may serve as useful clinical tools for evaluating speech identification abilities in Malayalam-speaking children. The findings of the study also highlight the importance of considering age and listening environment while assessing speech perception performance in children and support the need for speech perception testing under ecologically valid listening conditions involving background noise.

5.1 Implications of the Study

The Malayalam high-frequency word lists developed in the present study can serve as a useful clinical tool for assessing speech perception abilities in Malayalam-speaking children. The developed lists can be useful for assessing speech identification performance under both quiet and noise listening conditions which provide a more reliable real world understanding of listening abilities in children. The inclusion of both quiet and noise listening conditions increases the ecological validity of the test, as children commonly encounter environments such as classrooms and playgrounds in everyday life which make speech perception more challenging.

Therefore, the developed SIS materials may assist audiologists in evaluating real-world speech perception difficulties more effectively and accurately.

5.2 Future Directions

- The present study was done on limited number of participants and hence future research can be done in higher sample size for increasing the generalizability of the test material across Malayalam speaking children.
- The developed material may be evaluated in children with hearing impairment, auditory processing disorders, and other communication disorders to establish their clinical applicability in disordered populations.
- Since the present study included children within a limited age range, future studies may extend the age range to include younger children and adolescents for developing age-specific normative data for that population.
- In addition, the developed Malayalam high frequency word lists may be utilized in studies involving hearing aid users and cochlear implant recipients to evaluate auditory rehabilitation outcomes and speech perception abilities in realistic listening conditions.

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APPENDIX: I

List 1

(Bisyllabic Words)

Half List -1		**Half List -2**	
ചന്ദ്രൻ	/tʃan̪d̪ɾan/	ചേര	/tʃeːɾa/
ചോദ്യം	/tʃoːd̪jam/	സൂചി	/suːtʃi/
ശത്രു	/ʃat̪ɾu/	സ്ലേറ്റ്	/sleːt̪t̪ə/
ചിഹ്നം	/tʃiɦn̪am/	സീബ്ര	/siːbra/
ചേമ്പ്	/tʃeːmpə/	ചതി	/tʃat̪i/
ചിക്കൻ	/tʃikkan/	ശബ്ദം	/ʃabd̪am/
ശക്തി	/ʃakt̪i/	ചക്ക	/tʃakka/
സാരി	/saːɾi/	കിണർ	/kiɳar/
ചേച്ചി	/tʃeːtʃtʃi/	ചുറ്റും	/tʃut̪t̪um/
സുർക്ക	/surkka/	സ്വർഗം	/sʋargam/
ചലം	/tʃalam/	ചിത്രം	/tʃit̪ɾam/
ചെടി	/tʃeʈi/	ചൂരൽ	/tʃuːɾal/
ചോര	/tʃoːɾa/	കഷ്ടം	/kaʂʈʈam/
സസ്യം	/sasjam/	കീരി	/kiːɾi/
ഷർട്ട്	/ʂarʈʈə/	കൃഷി	/krɨʂi/
ശെരി	/ʃeɾi/	ചോളം	/tʃoːɭam/
ചെണ്ട	/tʃeɳʈa/	സ്ഥിരം	/st̪ʰiɾam/
സ്നേഹം	/sneːɦam/	സാധു	/saːd̪ʱu/
പേജ്	/peːɟə/	ഇഞ്ചി	/iɲtʃi/
ശനി	/ʃani/	ഷീറ്റ്	/ʂiːʈʈə/
ചോർച്ച	/tʃoːrtʃtʃa/	ചുമർ	/tʃumar/
ശിവൻ	/ʃiʋan/	സൂര്യ	/suːɾja/
ചിരി	/tʃiɾi/	ചിതൽ	/tʃit̪al/
ചാത്തൻ	/tʃaːt̪t̪an/	ചാടി	/tʃaːʈi/
കോഴി	/koːɻi/	ചുണ്ടൽ	/tʃuːɳʈal/

APPENDIX: II

List 2

(Bisyllabic Words)

Half List -1		Half List -2	
കേസ്	/keːsə/	ചട്ടി	/t͡ʃaʈʈi/
സലാം	/salaːm/	ശവം	/ʃaʋam/
സ്വർണ്ണം	/sʋarɳam/	ചക്രം	/t͡ʃakram/
സോഡ	/soːɖa/	ചാനൽ	/t͡ʃaːnal/
സിംഹം	/simɦam/	സദ്യ	/sad̪ja/
അഞ്ചു	/aɲt͡ʃu/	ചാക്ക്	/t͡ʃaːkkə/
ചുണ്ട്	/t͡ʃuɳʈə/	സ്രാവ്	/sraːʋə/
ചേട്ടൻ	/t͡ʃeːʈʈan/	ചെളി	/t͡ʃeɭi/
ചൂട്	/t͡ʃuːʈə/	സീത	/siːt̪a/
എലി	/eli/	സോപ്പ്	/soːppə/
സാക്ഷി	/saːkʂi/	ക്രിസ്തു	/krist̪u/
ശ്രമം	/ʃramam/	ദേഷ്യം	/d̪eːʂjam/
ശേഷം	/ʃeːʂam/	ദോഷം	/d̪oːʂam/
കൃഷ്ണൻ	/krɨʂɳan/	ചാട്ടം	/t͡ʃaːʈʈam/
ഷോക്ക്	/ʂoːkkə/	ചീപ്പ്	/t͡ʃiːppə/
സത്യം	/sat̪jam/	ചിപ്പി	/t͡ʃippi/
ചീത്ത	/t͡ʃiːt̪t̪a/	സുഖം	/sukʰam/
ഭാഷ	/bʱaːʂa/	കിളി	/kiɭi/
ചോക്ക്	/t͡ʃoːkkə/	ചിറ്റ	/t͡ʃit̠t̠a/
സ്വാദ്	/sʋaːd̪ə/	സ്വയം	/sʋajam/
ജയിച്ചു	/ɟanam/	സൈക്കിൾ	/sai̯kkiɭ/
സോഫ	/soːfa/	ചെവി	/t͡ʃeʋi/
പൂജ്യം	/puːɟjam/	ജയിൽ	/ɟajil/
ശിക്ഷ	/ʃikʂa/	സഞ്ചി	/saɲt͡ʃi/
ഷീല	/ʂiːla/	ശ്വാസം	/ʃʋaːsam/

APPENDIX: III

List 3

(Trisyllabic Words)

Half List -1		Half List -2	
സംസാരം	/samsaːɾam/	സിനിമ	/sinima/
വിജയം	/ʋiɟajam/	ചങ്ങല	/tʃaŋŋala/
ചിലന്തി	/tʃilant̪i/	കുറുക്കൻ	/kurukkan/
രഹസ്യം	/ɾaɦasjam/	ചികിത്സ	/tʃikit̪sa/
കസേര	/kaseːɾa/	മസാല	/masaːla/
ചെകുത്താൻ	/tʃekut̪t̪aːn/	ആഘോഷം	/aːgʱoːʂam/
സന്തോഷം	/sant̪oːʂam/	ചങ്ങാതി	/tʃaŋŋaːt̪i/
ചിരട്ട	/tʃiraʈʈa/	ചേട്ടത്തി	/tʃeːʈʈat̪t̪i/
സംസ്ഥാനം	/samst̪ʰaːnam/	കാബേജ്	/kaːbeːɟə/
ചതുരം	/tʃat̪uɾam/	ജീവിതം	/ɟiːʋit̪am/
പൊലീസ്	/poːliːsə/	ഇസ്തിരി	/ist̪iɾi/
ചുറ്റിക	/tʃut̪t̪ika/	കഷണ്ടി	/kaʂaɳʈi/
ചെങ്കണ്ണ്	/tʃeŋkaɳɳə/	ഇളക്കുക	/iɭakki/
കയറ്റം	/kajat̪t̪am/	ജീവികൾ	/ɟiːʋikaɭ/
ചെറുത്	/tʃerut̪ə/	കക്ഷം	/kakʂam/
ചതവ്	/tʃat̪aʋə/	സഹായം	/saɦaːjam/
സാധനം	/saːd̪ʱanam/	കഷണം	/kaʂaɳam/
ചിരവ	/tʃiraʋa/	ചരിഞ്ഞു	/tʃeriɲɲu/
ശുചിത്വം	/ʃutʃit̪ʋam/	സന്യാസി	/sanjaːsi/
ചെറുപ്പം	/tʃeruppam/	സ്വകാര്യം	/sʋakaːɾjam/
ചക്കര	/tʃakkaɾa/	കഷായം	/kaʂaːjam/
ചുഴലി	/tʃuɻali/	ഇഷ്ടിക	/iʂʈika/
ചട്ടുകം	/tʃaʈʈukam/	സമ്മതം	/sammat̪am/
ചമ്മന്തി	/tʃammant̪i/	പ്രസംഗം	/prasamgam/
കച്ചോടം	/katʃtʃoːʈam/	ചോക്ലേറ്റ്	/tʃoːkleːt̪t̪ə/

APPENDIX IV

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.4/AUD. 09/2025-26 **Date: 06.01.2026**

Title of the Dissertation : Development of a High-Frequency Wordlist for Children in Malayalam

Name of the Investigator : Mr. Aswinlal K
Guide : Dr. Chandni Jain
Co-Guide (if any) : --
Proposed Duration of the Project : 08 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 : 02.01.2026

A clear statement of the decision reached IRB meeting
(In the vent of the proposal is not approved, a statement
of reasons for the same must be indicated) : **APPROVED**

Advice & suggestions (if any) : To submit a permission letter from the institution of data collection

Signature & Name of the Member Secretary-IRB
Dr. Animesh Barman
Professor of Audiology
All India Institute of Speech and Hearing, Mysore-570006

सदस्य सचिव / Member Secretary
संस्थागत समीक्ष बोर्ड
Institutional Review Board
अखिल भारतीय वाक् श्रवण संस्थान
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