DEVELOPMENT AND VALIDATION OF COMPETING SENTENCE TEST IN HINDI

(CST-H)

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CERTIFICATE

This is to certify that this dissertation entitled **'Development and Validation of Competing Sentence Test in Hindi (CST-H)'** is a Bonafide work submitted as part of fulfilment of the degree of Master of Science (Audiology) of the student with Registration Number **P01II24S023034**. This has been carried out under the guidance of a faculty of this institute and has not been submitted earlier to any other university for the award of any other Diploma or Degree.

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DECLARATION

This is to certify that this dissertation entitled **'Development and Validation of Competing Sentence Test in Hindi (CST-H)'** is the result of my own study under the guidance of Dr. Sahana P., Assistant Professor of Audiology, All India Institute of Speech and Hearing, Mysuru and has not been submitted earlier to any other university for the award of any other Diploma or Degree.

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ABSTRACT

Background: *Central Auditory Processing Disorder [(C)APD] refers to deficits in the neural processing of auditory information within the central auditory nervous system (CANS), different from peripheral hearing loss. Among the core auditory skills affected in (C)APD, binaural separation — the ability to attend selectively to one ear while ignoring a competing signal in the other ear — is clinically significant and is commonly assessed using the Competing Sentence Test (CST). Existing versions of the CST, however, were developed and standardised for English-speaking populations and are not linguistically or culturally suitable for Hindi-speaking children. Hindi follows a Subject–Object–Verb (SOV) grammatical structure, which differs fundamentally from the Subject–Verb–Object (SVO) structure of English, leading to direct translation being invalid.*

Aim: *The primary aim of the present study was to develop and validate the Competing Sentence Test in Hindi (CST-H) and to establish age-specific test-scoring data for assessing binaural separation skills in typically developing, native Hindi-speaking children aged 8 to 11 years.*

Method: *The study was conducted in two phases. In Phase I, 125 sentence pairs were developed using grammatically and semantically natural Hindi sentences, controlled for length, syntactic complexity and lexical familiarity. Content validity was established through expert review by 3 native Hindi-speaking primary school teachers and 5 children who did not participate in the second phase of the study, providing a shortlist of 70 sentence pairs. Sentences were recorded by a male native Hindi speaker using a Behringer B2 Pro studio microphone, edited and normalised in Adobe Audition at 44.1 kHz and 24-bit resolution. Audiologist validation of recorded sentences on a 5-point Likert scale reduced the set to 41 pairs, from which a final set of 35 sentence pairs was selected for the CST-H. Keywords were* *identified by a native Hindi-speaking primary school teacher. Stimulus presentation was automated using MATLAB R2014b platform at a target-to-competing sentence ratio of −15 dB.*

In Phase II, 40 typically developing, right-handed, native Hindi-speaking children were recruited from a mainstream school in Bhopal, Madhya Pradesh, and assigned to four age groups of 10 participants each (8–8.11, 9–9.11, 10–10.11, and 11–11.11 years). All participants exhibited normal peripheral hearing sensitivity (pure-tone averages ≤20 dB HL) and passed the Screening Checklist for Auditory Processing (SCAP). The CST-H was administered dichotically through calibrated Sony WH-CH720n headphones via MATLAB, with the target sentence presented at 35 dB SL and the competing sentence at 50 dB SL (Ref: SRT). Scoring was based on the correct repetition of pre-identified keywords (up to 30 per ear). Test-retest reliability was assessed in a subgroup of 20 participants after a 10-day interval. Nonparametric statistical procedures (Kruskal–Wallis and Wilcoxon signed-rank tests; Spearman rank-order correlation) were applied in SPSS v26, given predominantly non-normal score distributions confirmed by Shapiro–Wilk testing of normality.

Results: *Right-ear (RE) scores ranged from a group mean of 25.30 (SD = 0.68) in Group 1 (8-8.11 years) to 29.20 (SD = 0.79) in Group 4 (11-11.11 years), while left-ear (LE) scores increased from 24.00 (SD = 0.67) to 28.10 (SD = 0.88) over the same group range, respectively. Kruskal–Wallis tests revealed statistically significant age-related differences for both RE ($p < .001$) and LE ($p < .001$) scores, with the most pronounced improvement observed between the Group 1 and Group 4 through post hoc Dunn's test for both ear scores ($p < .001$). Wilcoxon signed-rank tests confirmed a statistically significant right-ear advantage (REA) across all four age groups (all $p < .05$), with higher right-ear scores. Test-retest reliability was excellent for both the right ear ($r_s = .866$, $p < .001$) and left ear ($r_s = .870$, $p < .001$).*

Conclusion: *The CST-H demonstrated satisfactory psychometric properties, providing age-differentiated, ear-asymmetric test scoring data with excellent test-retest reliability. The age-specific ±2 standard deviation (SD) test score ranges provide the cut-off scores for identifying binaural separation deficits in Hindi-speaking children, thereby supporting the differential diagnosis of (C)APD in this population. The consistent REA observed across all age groups is consistent with established models of left-hemisphere dominance for speech processing and the developmental maturation of the CANS.*

CHAPTER I

INTRODUCTION

Hearing is one of the most fundamental senses through which humans interact with their environment. From the moment sound enters the ear canal until it is perceived as meaningful speech or music, a highly complex biological process unfolds across multiple levels of the auditory system (Kunchur, 2023). The peripheral hearing mechanism — comprising the outer, middle, and inner ear — is responsible for detecting and transforming acoustic energy into neural signals. But detection alone is not perception. For sound to acquire meaning, those neural signals must travel through and be interpreted by a highly organised network of subcortical and cortical structures known as the central auditory nervous system (CANS) (Kunchur, 2023).

The CANS processes a range of complex perceptual functions that extend beyond simple sound detection. These include sound localisation, auditory discrimination, pattern recognition, and the temporal processing of auditory signals — including temporal resolution, masking, integration, and ordering (ASHA, 2005). In addition, this also supports speech understanding in degraded or challenging listening conditions, such as noisy environments or distorted acoustic signals (Musiek, 1983). This central auditory processing ability allows efficient communication in a noisy environment, focused attention to the target message, and recognition of familiar auditory patterns even in background interference (Pinheiro & Musiek, 1985).

When these central processes are impaired— even in individuals whose peripheral hearing is completely within normal limits — significant and often pronounced auditory processing difficulties may arise. This impairment in central auditory processing of auditory information is referred to as (Central) Auditory Processing Disorder, or (C)APD. Unlike peripheral hearing loss, which primarily affects the detection of sound, (C)APD involves deficits in auditory processing, where the peripheral hearing system may function normally, but the central auditory nervous system has difficulty efficiently processing and interpreting the auditory information received (Musiek & Chermak, 2014).

The American Speech-Language-Hearing Association (2005) defines (C)APD as deficits in the neural processing of auditory information in the CANS that are not attributable to higher-order language or cognitive factors. Clinically, the diagnosis requires poor performance in one or more of the following domains: sound localisation and lateralisation, auditory discrimination, auditory pattern recognition, temporal aspects of audition (including temporal resolution, masking, integration, and ordering), auditory performance with competing acoustic signals, and auditory performance with degraded acoustic signals. This definition position (C)APD clearly within the auditory domain while recognising the complexity of separating it from co-occurring cognitive and linguistic difficulties.

While (C)APD affects many auditory functions, binaural processing is central to both its clinical and neurobiological impact. It generally refers to the brain's ability to combine and compare signals arriving from both ears.

Binaural integration refers to central auditory nervous system’s ability to processes signals presented to each ear simultaneously. In the dichotic listening tasks, participants have to focus sounds coming from both ears (Bellis, 2003). Neuroanatomically, this process is closely associated with the Superior Olivary Complex (SOC), where inputs from both ears converge to enable effective binaural hearing (Zhang et al., 2023).

Binaural separation, in contrast, is the ability of CANS to discriminate and attend selectively to one of two different signals delivered at the same time to each ear (Ohta et al., 1967). The SOC plays a Critical role in processing the interaural time differences (ITD) and interaural level differences (ILD) that support binaural separation (Ozmeral & Higgins, 2022).

Among the two processes binaural interaction refers to the broader neural process by which signals from both ears are combined as they ascend through the auditory pathway, contributing to the perception of spatial location and the detection of signals against background interference (Blauert & Butler, 1985; Durlach et al., 1981). This interaction occurs at multiple levels of the brainstem, including the SOC, the nuclei of the lateral lemniscus, and the inferior colliculus (Moore, 1991).

Sound localisation and lateralisation represent important aspects of binaural processing. Sound localisation refers to the ability to determine the position of a sound source in external space based on its direction and distance, whereas lateralisation refers to the perception of a sound source within the head, which is commonly experienced during earphone listening (Carlini et al., 2024). The medial superior olive (MSO) and lateral superior olive (LSO) play major roles in sound localisation, while lateralisation has been associated with Heschl's gyrus and the primary auditory cortex, particularly in the left hemisphere (Tollin, 2003).

Given the important role of binaural processing in everyday communication, problems or difficulties in these abilities can substantially affect academic performance, communication, and listening in challenging environments, particularly in children. Difficulties in binaural separation and integration are commonly observed in individuals with (C)APD and are often frequently assessed using dichotic listening tasks, which are considered sensitive measures of central auditory functioning (Musiek & Chermak, 2014). However, accurate identification of such deficits requires linguistically and culturally appropriate assessment tools along with the availability of age-specific normative data. In multilingual contexts such as India, the availability of standardised dichotic tests in regional languages is limited, which can affect accurate diagnosis and clinical interpretation in paediatric populations. These limitations emphasise the need to develop and standardise culturally relevant assessment tools for Hindi-speaking children.

1.1 Need for the study

The present study addresses the limited availability of standardised dichotic listening tools in India, particularly for Hindi-speaking children. Therefore, there is a need for assessment tools that are both linguistically appropriate and relevant to the target Hindi population to address the cultural-linguistic differences, and age-related language development can also influence test performance

1.1.1 Lack of Standardised Tools in India

The practice of audiology in India faces significant challenges due to its broad linguistic diversity. The nation has 22 officially recognised languages, which include hundreds of dialects (Bantwal, 2011). As a result, clinicians often find it difficult to access linguistically and culturally appropriate tools. This gap affects the reliability and accuracy of (C)APD diagnosis in many individuals.

Currently available diagnostic materials, such as the Competing Sentence Test (CST), originally developed for English-speaking populations, may not be clinically appropriate or psychometrically valid for use with Hindi-speaking children. (Bantwal, 2011). The continued reliance on such foreign assessment materials may result in inconsistent diagnostic practices. Clinicians often differ considerably in their approaches to assessing (C)APD. A survey by Swetha et al. in 2024, conducted among audiologists in Kerala revealed that although many professionals screened children for (C)APD, only a small number used standardised assessment tools, with most depending on non-standardised speech-in-noise tests. Together, these issues emphasise the urgent need for validated, standardised, culturally relevant assessment tools for Indian populations.

1.1.2 Linguistic and Cultural Factors

The linguistic differences between English and Hindi limit the validity of English CSTs when used with Indian children. The formation of sentences following Subject-Verb-Object (SVO) word order in English creates a huge difference in the way competing auditory messages interfere with target sentences during dichotic listening tasks in the Hindi population that follows a Subject-Object-Verb (SOV) structure (Rhythm et al., 2024). Therefore, there is a need to develop a Hindi CST using sentences that are grammatically and semantically natural in Hindi to ensure appropriate psychometric validity.

Cultural familiarity plays an important role in test performance; sentences developed for Western children may include words, contexts, and semantic categories that are not appropriate for the Indian context. The lack of ecological validity can negatively influence performance and may lead to unnecessarily high rates of (C)APD diagnosis in children whose difficulties arise primarily from cultural unfamiliarity rather than true auditory processing deficit (Grebenyuk et al., 2025).

Therefore, developing a Hindi CST involves much more than simply translating existing test materials. Researchers must develop assessment tools that are culturally relevant, ecologically valid, and linguistically appropriate for India's largest language-speaking population.

1.1.3 Age-Specific Auditory Development

Auditory pathways continue to mature throughout childhood and into adolescence. Neuromaturation processes such as myelination and synaptic pruning improve the efficiency of auditory and language networks over time (Devous et al., 2006). Research has shown that although the primary auditory cortex reaches functional maturity by around 7 years of age, higher-order areas such as Wernicke's area and the angular gyrus continue to mature into the teenage years (Corbin et al., 2016).

The ongoing maturation influences performance on tasks such as the CST, which evaluate binaural separation. These auditory skills continue to develop until approximately 12 years of age, with adult-like performance typically observed between 13-14 years (Corbin et al., 2016). Studies have also reported that younger children aged 8-9 years perform more poorly than older children aged 11-12 years on CST-related tasks (Rhythm et al., 2024).

These findings highlight the importance of establishing age-specific normative data for the CST-H. In the absence of such norms, younger children may be incorrectly identified as having auditory processing difficulties, while older children with genuine deficits may be overlooked. Therefore, a Hindi CST should include developmentally stratified normative data to support accurate diagnosis of (C)APD during childhood.

1.2 Aim of the Study

The primary aim of the present study was to develop and validate the Competing Sentence Test in Hindi (CST-H) and to establish age-specific test scores for assessing binaural separation abilities in typically developing Hindi-speaking children.

1.3 Objectives of the Study

The specific objectives of the study include:

1. To develop 35 pairs of Hindi sentences suitable for children between 8 and 11 years of age.
2. To record the sentence stimuli and validate them for content accuracy as well as sound quality.
3. To develop a standardised procedure for administering and scoring the CST-H using a MATLAB-based platform.
4. To establish age-specific test scoring data for developed CST-H in children aged 8 to 11 years.

5. To examine the test-retest reliability of the developed CST-H.

CHAPTER II

REVIEW OF LITERATURE

(Central) Auditory Processing Disorder [(C)APD] represents a significant challenge within audiology, impacting an individual's academic success, language acquisition, and social communication (Willeford & Burleigh, 1994). The American Speech-Language-Hearing Association (ASHA) defines (C)APD as a deficit in the neural processing of auditory information within the central auditory nervous system (CANS) that is not attributable to higher-order cognitive, language, or related deficits (*ASHA 2005 CAPD Statement*, n.d.).

Individuals with (C)APD, despite having normal peripheral hearing sensitivity, often experience significant difficulty understanding speech, particularly in acoustically challenging environments such as noisy classrooms or reverberant spaces. Although the clinical impact of (C)APD is widely accepted, the diagnosis remains one of the most debated topics in the field, complicated by methodological inconsistencies and theoretical disagreements (Ismen & Emanuel, 2023).

2.1 Limitations of Peripheral and Functional Hearing Assessments

Pure Tone Audiometry (PTA) is one of the important tests for evaluating peripheral hearing loss, which measures an individual's sensitivity to simple, frequency-specific tones. While PTA is essential for identifying hearing loss originating in the outer, middle, or inner ear, it provides limited insight into how the brain processes sound (Hodgson, 1967). He reported on a patient with an entire cerebral hemisphere surgically removed who presented with normal pure-tone thresholds. This case demonstrates that a normal audiogram does not rule out central auditory processing disorders. It highlights the need for additional behavioural and electrophysiological tests.

We can understand this diagnostic limitation of PTA through the complex interaction between bottom-up and top-down auditory processing. As Bottom-up processing refers to the sensory-driven encoding of physical and acoustic properties of a signal, such as frequency, intensity and timing, within the CANS (Moore, 2012). Top-down processing, by contrast, involves higher-order cognitive functions, including working memory, attention, and linguistic expectations, which are used to interpret degraded auditory information (Moore, 2012). As PTA measures bottom-up detection of sounds, it cannot account for the brain's processing of auditory information after detection. Further Speech-in-noise tests were developed to address top-down processing demands. It offers a more ecologically valid measure of listening ability, but such tests, when used in isolation, lack the sensitivity and specificity for a definitive (C)APD diagnosis (Ismen & Emanuel, 2023). This discrepancy required a shift toward assessment tools specifically developed to evaluate the integrity of central auditory mechanisms.

2.2 Defining (C)APD and its Diagnostic Challenges

The core diagnostic challenge lies in (C)APD’s inherent complexity and persistent difficulties in assessing it. There is a lack of a single accepted test battery that everyone agrees on, which leads to variability in diagnostic practices across clinics and research centres worldwide (Gitto et al., 2025). (C)APD characteristics look a lot like other neurodevelopmental disorders- specifically, Attention-Deficit/Hyperactivity Disorder (ADHD), Specific Language Impairment (SLI), and learning disabilities. Behaviours such as difficulty listening in noise, inattentiveness, poor academic performance, and inconsistent responses to auditory information appear in all these conditions. This makes differential diagnosis difficult and blurs the boundaries between a primary auditory deficit and a deficit in attention, language, or executive function (de Wit et al., 2018).

This absence of distinct characteristics has created a controversial debate about the status of (C)APD as a separate clinical disorder. Many critics question the validity of (C)APD, suggesting that what appear to be specific auditory problems are actually driven by broader cognitive or language deficits rather than a standalone disorder (Ismen & Emanuel, 2023). Proponents maintain that (C)APD is a valid and verifiable disorder that can be accurately identified through a deficit-specific battery of behavioural and electrophysiological tests (Ismen & Emanuel, 2023). This justifies the need for the development of a competing sentence test.

2.3 The Dichotic Listening Paradigm

To examine the CANS, the researchers rely on dichotic listening. This non-invasive method gives us a clear picture of both the auditory pathways and the brain networks required for complex listening paradigms (Westerhausen, 2019a). By presenting competing auditory information simultaneously to both ears, dichotic tasks create a condition of auditory stress that reveals the efficiency of hemispheric specialisation, interhemispheric communication, and auditory selective attention (Andersson et al., 2008; Westerhausen & Hugdahl, 2008).

2.3.1 Foundational Principles

The dichotic listening paradigm was pioneered by Broadbent (1957) in the development of the filter model of attention and later utilised by Kimura (1967) to investigate the lateralisation of brain function. While each ear projects auditory information to both cerebral hemispheres, the contralateral pathways are anatomically more robust and functionally dominant under conditions of dichotic competition (Kimura, 1967). This pathway is particularly crucial for speech sounds. In most right-handed people, the left hemisphere serves as the primary area for processing language (Kimura, 1967). The reason this is important lies in the dominance of crossed auditory pathways: speech presented to the right ear gets relatively direct access to the left hemisphere's language centres. By contrast, left-ear inputs take the long way around—they reach the right hemisphere first and must rely on interhemispheric transfer via the corpus callosum for language processing (Kimura, 1967). This asymmetry explains the Right Ear Advantage (REA), a well-documented finding in which normal-hearing listeners easily outperform their left ears when reporting right-ear verbal targets (Hugdahl, 2011). The presence, magnitude, or absence of the REA serves as a valuable clinical indicator of CANS maturation and integrity (Westerhausen, 2019).

2.3.2 Core Auditory Skills Assessed through the dichotic test

Dichotic listening tasks aim to measure two distinct central auditory skills. First is binaural integration- in other words, the ability to process information presented to both ears simultaneously. With this skill, the listener needs to attend to and report stimuli from both ears, which is usually tested using tests like the Dichotic Digits Test (Musiek, 1983). The second skill is binaural separation. Here's the key difference: instead of attending to both ears, the listener must attend to a stimulus presented to one target ear while actively ignoring a competing stimulus in the other ear (Payne et al., 2017). This skill is fundamental to selective auditory attention and becomes absolutely essential in complex listening environments where one has to focus on a single conversation in the presence of competing noise — the phenomenon commonly known as the cocktail party effect (Hill & Miller, 2010).

The competing sentence test serves as a primary measure of binaural separation. (Willeford & Burleigh, 1985). Poor performance on binaural separation tasks may point to failure of top-down executive control networks that modulate auditory processing. It provides a more specific diagnostic hypothesis than general speech-in-noise tests (Westerhausen & Hugdahl, 2008).

2.3.3 Relevance to (C)APD and Neurodevelopment

The dichotic listening paradigm is valued for its high ecological validity as it simulates the auditory demands of everyday complex listening environments. Classroom environment and group conversation require the ability to separate a target message from competing auditory distractors (Nagaraj et al., 2020). Performance on dichotic listening tasks is closely linked to the neurodevelopmental trajectory of the CANS, as the key auditory structures, including the corpus callosum and higher-order association cortices, continue to mature through myelination and synaptic pruning well into adolescence (Musiek & Chermak, 2014; Westerhausen & Hugdahl, 2008). This ongoing neurological development shows up clearly in behavioural performance. Children show systematic improvements in dichotic listening skills with increasing age (Moncrieff, 2011). This maturational effect makes it absolutely important to establish age-specific normative data for any dichotic test intended for use with a paediatric population. Without such norms, it is impossible to distinguish clinically significant deficits from normal developmental immaturity (ASHA, 2005).

2.4 The Competing Sentence Test

2.4.1 Origins and Development

The Competing Sentence Test (CST) was first developed by Willeford (1977) as a core part of a test battery meant to identify lesions within the central auditory pathways. This test used semantically related sentence pairs of similar length, presented dichotically at a message-to-noise ratio of -15 dB. This particular ratio was not random, as it was chosen to really challenge the higher auditory centres and avoid ceiling effects in normal listeners (Lvey & Willeford, 1988).

The foundational concept of using competing sentences was further used in more widely distributed test batteries. Most importantly, Keith (2000) included a Competing

Sentences subtest in the Screening Test for Auditory Processing Disorders in Children (SCAN-C), which gave clinicians a standardised means of assessing how children utilise linguistic cues to interpret speech when faced with competing messages.

2.4.2 Principles Involved in the Development of the Competing Sentence Test

The development of a competing-sentence test involves balancing psychometric, acoustic, linguistic, and standardisation principles. From a psychometric perspective, one needs to establish test-retest reliability to confirm that performance scores stay consistent across administrations. At the same time, construct and content validity mean that test items actually reflect the auditory processing demands associated with binaural separation rather than confounding variables such as vocabulary knowledge or cognitive load (ASHA CAPD Statement, 2005). Another critical thing is that the Sensitivity and specificity for binaural processing deficits must be empirically determined. This ensures the test can tell the difference between the disordered population and typically developing peers (Bellis, 2011).

Acoustically, the message-to-competing-ratio is the primary factor to consider for task difficulty. The target sentences are presented at 15 dB lower than the competing message, i.e., -15 dB ratio is commonly used to provide an adequate perceptual challenge while maintaining the clinical suitability of the task (Lvey & Willeford, 1988). The spectral characteristics of the competing signal also influence task difficulty. Greater acoustic overlap occurs when the competing sentence is spoken by a talker of the same gender as the target talker. This increases the sensitivity of the test to binaural processing deficits (Bellis, 2011).

Linguistically, sentence length should be controlled to minimise working memory demands, with sentences of five to eight words generally preferred (Lvey & Willeford, 1988). Syntactic complexity, phonetic balance, and lexical familiarity should be matched across sentence sets so that performance differences reflect auditory separation ability rather than differential processing of grammatical or lexical features (ASHA, 2005).

From a standardisation perspective, comprehensive normative data must be derived from samples stratified by age, given the documented developmental trajectory of binaural processing across childhood (Bellis, 2011; Musiek, 1983). The tests are intended for use across linguistic communities, adaptation and re-normalisation are required to preserve construct equivalence, as phonological, lexical, and prosodic differences between languages directly affect competing sentence intelligibility (*ASHA 2005 CAPD Statement*, 2005; Keith, 2000).

2.4.3 Clinical Utility and Advantages

The primary function of the CST is to assess binaural separation by testing directed auditory attention. It requires the listener to focus on the sentence in a target ear while actively ignoring the competing sentence in the non-target ear (Lvey & Willeford, 1988). Compared with other binaural separation paradigms, such as the Synthetic Sentence Identification with Contralateral Competing Message (SSI-CCM) and the Pediatric Speech Intelligibility (PSI) test, the CST demonstrates superior ecological validity because it uses linguistically enriched, connected speech. while SSI-CCM uses third-order synthetic sentences that lack natural meaning (Bellis, 2011). PSI employs simplified structures designed for younger children that may produce ceiling effects masking subtle processing difficulties in school-aged populations. By contrast, the CST engages the listener's syntactic and semantic processing, more accurately simulating the complex auditory demands of a classroom and everyday listening conditions (Hugdahl, 2011; Lvey & Willeford, 1988).

The CST is also uniquely sensitive to cortical dysfunction, particularly within the temporal lobes, due to its use of linguistically complex stimuli and an open-set response format (Lvey & Willeford, 1988). Its results translate directly into real-world management strategies as performance patterns on the CST provide a clear rationale for accommodations such as FM systems or preferential seating to improve the listening signal-to-noise ratio (Bishop, 2007; Keith, 2000). Ismen & Emanuel (2023) noted that the functional relevance of the CST is a primary reason it features prominently in contemporary (C)APD diagnostic batteries.

2.4.4 Psychometric Properties

Studies on the SCAN-C, which includes the Competing Sentences subtest, have reported good test-retest reliability, with correlation coefficients for individual subtests ranging from 0.65 to 0.82 in children aged 5 to 7 years (Keith, 2000). Factor analysis of the SCAN-C battery has demonstrated that the Competing Words and Competing Sentences subtests load together onto a distinct binaural separation factor, separate from a monaural low-redundancy factor comprising tests such as Filtered Words (Bishop, 2007) confirming that the CST measures a specific and distinct auditory processing construct.

A major limitation of commercially available English-language versions of the CST is their standardisation in American English (Willeford & Burleigh, 1985b), rendering them inappropriate for non-native English speakers and highlighting the need for language-specific adaptations.

Table 2.1.

Comparison of Competing Sentence Tests Used in Central Auditory Processing Assessment

Test	Developer(s)	Stimulus Type	Skill Assessed	Key Features	Sources
CST	Willeford (1977)	Pairs of meaningful sentences	Binaural separation	High ecological validity; −15 dB MCR; sensitive to cortical lesions	Ivey & Willeford (1988)
SSI-CCM	Jerger (1970)	Synthetic sentences (meaningless)	Binaural separation	Reduces top-down linguistic cues; varied MCRs; focuses on integrity of corpus callosum	Bellis (2011)
PSI	Jerger & Jerger (1984)	Simplified sentences	Binaural separation	Ages 3–6; picture-pointing response; effective for early developmental deficits	Bellis (2011)
CST-K	Rhythm et al. (2024)	Pairs of sentences (Kannada)	Binaural separation	Development in Indic-language ; age-specific norms; confirmed REA and developmental effects	Rhythm et al. (2024)

Note. CST = Competing Sentence Test; SSI-CCM = Synthetic Sentence Identification with Contralateral Competing Message; PSI = Paediatric Speech Intelligibility test; CST-K = Competing Sentence Test in Kannada; MCR = message-to-competition ratio; REA = right-ear advantage

2.5 The Importance of Age-Specific Normative Data

Age-specific normative data are critical in the assessment of (C)APD because the CANS is a maturing neurobiological system. Performance on dichotic listening tasks, including the CST, improves significantly throughout childhood as a result of the ongoing myelination of auditory pathways and the corpus callosum (Bellis, 2011; Musiek, 1983). Without age-specific norms, it is difficult to differentiate between a developmental delay, in which a child is maturing more slowly, and a true clinical deficit, in which the auditory system is dysfunctional. REA typically decreases, and left-ear scores increase as children approach adolescence. Clinicians should apply strictly defined age brackets to ensure diagnostic accuracy and avoid the risk of overdiagnosis or misdiagnosis (Bellis, 2011).

Age norms serve as a benchmark for assessing the integrity of the CANS. According to ASHA 2005 CAPD Statement guidelines, a diagnosis of (C)APD typically requires a performance deficit of at least two standard deviations below the normative mean on two or more tests in a test battery, reinforcing the necessity of robust, population-specific normative data. For a test like the CST, which involves high linguistic complexity, performance is additionally dependent on the child's level of language acquisition and exposure, further underscoring the need for normative samples derived from linguistically representative populations (ASHA, 2005; Bantwal, 2011).

2.6 Scoring and Interpretation of the CST

The CST is scored based on the accuracy of the listener's response in the designated target ear. The score generally depends on the percentage of correct keywords recalled from the target sentence (Lvey & Willeford, 1988). Along with the percentage score, clinicians also analyse the interaural asymmetry score, which is the difference between right-ear and left-ear percentage scores, considered as a sensitive indicator of unilateral processing deficits (Westerhausen & Kompus, 2018). Beyond quantitative scoring, clinicians should observe the type of errors produced and the listener's response latency, as these qualitative features provide additional insight into the cognitive and attentional load experienced by the child during testing (Ahmmed et al., 2014).

2.7 Factors Affecting Binaural Separation

2.7.1 Age

Age is one of the most investigated variables affecting binaural separation performance in children. The maturation of binaural processing follows a prolonged developmental timeline extending through adolescence, with progressive improvements reflecting myelination and synaptic maturation of the auditory pathways involved in corpus callosal transfer and cortical inhibition of the non-attended channel (Andersson et al., 2008; Musiek, 1983). CST indicate that binaural separation performance reaches maturity by approximately 10 years of age in most typically developing children (Lvey & Willeford, 1988), with gradual improvements evident in the years preceding this age.

2.7.2 Language Background

Language background exerts a meaningful influence on binaural separation performance because most clinical binaural separation tasks employ verbal stimuli (Price et al., 2025). A listener's proficiency in the language of the test material can significantly affect scores independently of any underlying auditory processing deficit (Price et al., 2025). Consequently, administering a test developed and normed in one language to speakers of another language risks producing clinically misleading results that reflect linguistic unfamiliarity rather than genuine auditory processing dysfunction (McNamara et al., 2025). This consideration provides a strong rationale for the development of competing sentence tests in languages other than English, particularly for linguistically diverse populations in countries such as India (Bantwal, 2011).

2.7.3 Message-to-Competition Ratio

The message-to-competition ratio (MCR), defined as the intensity level of the target message relative to the competing signal, has a well-documented effect on binaural separation performance. In the SSI-CCM protocol, the MCR is systematically varied to allow construction of performance-intensity functions that characterise the listener's capacity to separate the target from competition across a range of disadvantaged listening conditions (Jerger & Jerger, 1974). For the CST, a fixed MCR of −15 dB is standardly employed, placing the target sentence at a substantial disadvantage relative to the competing sentence and thereby maximising the sensitivity of the test to central auditory processing dysfunction (Lvey & Willeford, 1988).

2.8 Development of Competing Sentence Tests in Indian Languages

The linguistic and cultural diversity of India presents a unique challenge for audiological assessment, as the majority of standardised central auditory processing tests have been developed and normed exclusively for English-speaking populations (Bantwal, 2011b). The application of English-language tests to Hindi-speaking or other Indian-language-speaking children is methodologically inappropriate, as differences in phonological structure, lexical frequency, sentence prosody, and linguistic familiarity directly affect performance on competing-speech tasks and compromise the validity of normative comparisons (ASHA, 2005).

A significant recent contribution to this area is the development and validation of the Competing Sentence Test in Kannada (CST-K) by Rhythm et al. (2024), which established age-specific normative data for binaural separation in Kannada-speaking school-age children and confirmed the presence of a significant right-ear advantage and age-related improvement in performance. The CST-K demonstrated good to excellent test-retest reliability and represents a methodologically rigorous template for the development of competing sentence tests in other Indian languages (Rhythm et al., 2024). Prior to the development of the CST-K, no validated competing-sentence test existed for any Indian language, reflecting the broader underrepresentation of Indian languages in the central auditory processing assessment literature.

CHAPTER III

METHOD

The current study aimed to develop, validate and establish age-specific test scoring data for the Competing Sentence Test in Hindi (CST-H). This chapter further organises and provides step-wise details on the development and validation of the competing sentence test.

The study was carried out in two phases. Phase I involved the development, recording of stimuli and validation of a competing-sentence test in Hindi, while Phase II involved testing children aged 8 to 11 years to establish age-specific scoring data.

3.1 Phase I: Development and validation of stimuli

Phase I included the development, recording, and validation of Hindi sentence stimuli by adapting the following steps.

3.1.1 Step 1: Stimulus Selection

An initial set of about 250 simple, meaningful sentences was gathered from Hindi Grade 3 and Grade 4 academic textbooks, magazines, and day-to-day conversation. The academic textbooks that were used were the National Council of Educational Research and Training (NCERT) and the State Council of Educational Research & Training (SCERT) books.

The sentences were selected based on the following criteria:

1. Each sentence contained four to seven words,
2. The natural Subject–Object–Verb (SOV) structure of Hindi was followed,
3. The total number of syllables per sentence ranged from eight to nine,
4. All sentences that were syntactically correct and semantically neutral were included.

5. Lexical items were drawn from high- to moderate-frequency words in Hindi to ensure familiarity for school-age children,
6. Sentences were restricted to simple nouns, pronouns, and verbs, avoiding complex or rare constructions,
7. Emotionally loaded or emphatic expressions were excluded to maintain neutral prosody.
8. Sentences that contained only Hindi words, with no English or regional borrowings, were selected.
9. Sentences were constructed to prevent ambiguity or multiple interpretations.
10. Semantic neutrality was ensured by excluding content related to politics, war, or gender.
11. Sentences containing questions, proverbs, proper names, exclamations or duplicate sentences were not included.

3.1.2 Step 2: Content validation using the Content Validity Index method

A panel comprising three primary school teachers and five typically developing children (who did not participate in the main study) served as raters. The three teachers who served as raters were requested to evaluate each sentence pair across five domains, namely clarity, simplicity, acceptability (age-appropriateness), familiarity, and framing of the item (Chinnasamy et al., 2025). A three-point rating scale was used, with 1 indicating poor and requiring major revision, 2 indicating fair, and 3 indicating good.

Following this, the content validity of each item was established through the Content Validity Index (CVI) for each sentence pair per domain. At this stage, the item-level Content Validity Index (CVI) was calculated as the proportion of raters assigning a score of 3 using the following formula.

Item-Level Content Validity Index (CVI) = $\frac{\text{Number of raters giving a score of 3}}{\text{total number of raters}}$

For the scale-level CVI, the average of all item-level CVI values across the sentence pool was computed to determine the overall content validity of the developed sentence pairs. Content Validity Ratio (CVR) was calculated in accordance with the formula proposed by Lawshe (1975), as follows

$$\frac{ne - N\ /\ 2}{N\ /\ 2}$$

with 'ne' being the number of experts who rated the item as relevant (score of 3), and 'N' being the total number of experts

In accordance with established psychometric criteria for a three-member panel (Lynn, 1986; Polit & Beck, 2006), a Sentence pair with an I-CVI of 1.00 was considered relevant. Sentences with lower values or those requiring substantial revision based on expert suggestions were excluded.

Domain-specific analysis revealed a varying rate of item attrition. The highest consensus was observed within the domain of acceptability, where 113 sentence pairs achieved an I-CVI of 1.00, resulting in the elimination of 12 sentence pairs, followed by the familiarity domain, where 111 sentence pairs got an I-CVI of 1.00, and 14 were eliminated. Afterwards, for clarity, domain 108 sentence pairs got an I-CVI of 1.00; thus, 17 sentence pairs were eliminated. After clarity, in the framing domain, 97 sentence pairs had an I-CVI of 1.00, and 28 were rejected. Similarly, the highest rate of attrition was observed in the simplicity domain, where 94 sentence pairs achieved an I-CVI of 1.00, leading to the rejection of 31 sentence pairs. Finally, 91 sentence pairs were retained, as they achieved an I-CVI of 1.00 across all five domains; 34 were eliminated because they failed to meet the consensus threshold in one or more domains. Domain-specific data is available in Table 3.1.

Table 3.1

Content Validity Indices Across Five Domains (Stage 1)

Domain	Items with I-CVI=1	S-CVI/Ave	S-CVI/UA	Scale CVR
Clarity	108	1.00	1.00	1.00
Simplicity	94	1.00	1.00	1.00
Acceptability	113	1.00	1.00	1.00
Familiarity	111	1.00	1.00	1.00
Framing	97	1.00	1.00	1.00
Overall	91	1.00	1.00	—

Note. S-CVI/Ave = scale-level CVI Average; S-CVI/UA = scale-level CVI Universal agreement; Scale CVR = scale-level content validity ratio calculated using Lawshe's (1975) formula.

To evaluate the familiarity of the 91 sentence pairs retained after the teacher's validation, a panel of five children rated each item on a 5-point Likert scale (1= not familiar at all, 2= it is somewhat familiar, 3= quite familiar, 4= relevant, 5= very familiar). I-CVI, S-CVI (both Average and universal agreement) and content validity ratios were calculated following the procedure recommended by Lynn (1986), Polit and Beck (2006), and Lawshe (1975). At the item level,70 of 91 sentence pairs achieved an I-CVI of 1.00, indicating that all five children assigned a familiarity of 4 or 5, and the remaining 21 sentences pair were eliminated. CVR was computed for each sentence pair using lewshe's (1975) formula. The 70-sentence pair achieving I-CVI=1.00 correspondingly yielded CVR= 1.00, exceeding the critical value of 0.99 for five raters (Wilson et al., 2012). The 21 sentence pairs had a CVR of 0.60, which was below the critical value of 0.99 and were thus eliminated. In total, 70 sentence pairs were retained after children's familiarity validation.

Table 3.2

Content Validity Indices for Familiarity Ratings of 91 Sentence Pairs Rated by Five Children

Sentences pairs	CVI	Retained/ Eliminated
70*/91	1.00	Retained
21/91	0.80	Eliminated

Note. *Strict acceptable threshold for I-CVI = 1.00 (Lynn, 1986)

3.1.3 Step 3: Recording of stimuli

A male native Hindi speaker recorded the selected sentences with a standard, neutral accent. The speaker aimed to say each sentence with natural intonation and consistent vocal effort. The sentences were recorded with a Behringer B2 Pro dual-diaphragm studio microphone, placed 20 cm from the speakers' mouths. The recorded sentences were digitised and edited in Adobe Audition software at a sampling rate of 44.1 kHz and 24-bit resolution. The overall loudness of all sentence files was equalised using Root Mean Square (RMS) normalisation. The background noise was minimised using the adaptive noise reduction feature in Adobe Audition.

3.1.4 Step 4: Validation of recorded stimuli

The final set of recorded sentences was reviewed by a panel of three experienced, native Hindi-speaking audiologists. They evaluated each stimulus on a 5-point Likert scale for sound quality, clarity, distortion, and overall appropriateness for clinical use, rating 1 as strongly not recommended, 2 as not recommended, 3 as neutral, 4 as recommended, and 5 as strongly recommended. Audiologists were encouraged to provide open-ended feedback for further improvement of the sentence. Only those sentences that received a rating of 5 from all three audiologists were selected with an I-CVI of 1.00 as the criterion. At this stage, out of the 70 recorded sentences, 41 met this criterion and were shortlisted.

Table 3.3

Content Validity Metrics Across Four Domains for 70 Items Rated by Three Audiologists

Domain	I-CVI	S-CVI/Ave	S-CVI/UA	Mean CVR
Sound Quality	43*	1.00	1.00	0.60
Clarity	43*	1.00	1.00	0.63
Distortion	41*	1.00	1.00	0.58
Appropriateness	45*	1.00	1.00	0.67
Overall Test	41*	1.00	1.00	—

Note. *Criterion I-CVI of 1.00.

3.1.5 Step 5: Final Stimulus Set and Key Words Identification

Based on the validation feedback, at this stage, out of 41, a final set of 30 sentence pairs was selected for the main test, and 5 sentence pairs for practice with similar subject matter within each sentence pair; each pair of sentences (competing and target) was semantically related. Here, sentence pairs were eliminated because the gaps between utterances made them sound unnatural. One or two keywords (content words) were identified for each sentence by a primary school teacher who taught Hindi and was a native Hindi speaker, to ensure familiarity, meaningfulness and age-appropriateness of selected keywords. The keywords were defined as those words that were deemed to be important for comprehending for the comprehension of the sentence. The finalised CST-H sentence pairs are provided in Appendix I in Hindi and Appendix II in their IPA transcription with practice items.

3.1.6 Step 6: Development of the MATLAB program for the competing sentence

The length of the stimuli was standardised by adding silence to the end of the shorter stimulus within each pair, ensuring that both stimuli had equal duration for accurate comparison. The RMS (root mean square) amplitude of the target and interfering stimuli was carefully adjusted to achieve the desired and consistent stimulus level across all presentations. For precise calibration, the stimulus level was measured using an artificial ear in conjunction with a sound level meter (SLM), with levels expressed in terms of A-weighted RMS values. Finally, the entire stimulus presentation process was automated using MATLAB R2014b, which ensured accurate timing, consistency, and reproducibility throughout the procedure.

3.2 Phase II: Administration of tests to Children

The finalised competing-sentence test in Hindi was administered to four groups of children aged 8-11 to establish age-specific scoring data.

3.2.1 Research Design and Sampling

This study used a cross-sectional design to establish scoring data from typically developing Hindi-speaking children. A repeated-measures component assessed the test-retest reliability of the developed test material.

3.2.2 Ethical Approval

The study adhered to the Ethical Guidelines for Bio-behavioural Research Involving Human Subjects (AIISH, 2009) and obtained Institutional Review Board clearance (SH/IRB/M.4/AUD.26/2025-26). Before data collection, caregivers of all Children were provided with a brief explanation of the test procedures, and written informed consent was obtained.

3.2.3 Participants

A total of 40 right-handed children were recruited from mainstream schools in a Hindi-speaking area. School Children from the grade III to VI were enrolled for the study from Sandipani Higher Secondary Government school, located in Katara Hills, Barrai, Bhopal, Madhya Pradesh, Children were divided into four age groups, with 10 children per group. Group I was comprised of ten children in the age range 8 years to 8 years and 11 months (8-8.11 years), Group 2 included ten children between 9 years to 9 years and 11 months (9-9.11 years), Group 3 had ten children from 10 years to 10 years and 11 months (10-10.11 years) and Group 4 consisted children from 11 years to 11 years and 11 months (11-11.11 years).

3.2.3.1 Inclusion criteria. Children fulfilling the following criteria were included in the study:

- chronological age between 8 years to 11 years.
- Native Hindi speaker, with Hindi as the primary language of communication at home.
- Bilateral normal hearing sensitivity where the bilateral pure-tone air conduction thresholds must be ≤ 20 dB HL at octave frequencies from 500 Hz to 4 kHz.
- Must be right-handed.
- Pass from the Screening Checklist for Auditory Processing (SCAP)(Mascarenhas, 2004)

3.2.3.2 Exclusion criteria. Individuals were excluded from the study if any:

- History of chronic or recurrent otitis media or any other significant ear problem.
- A known or suspected neurological disorder, intellectual disability, psychological issue and speech-language impairment.

- Children with known learning disabilities, language disorders, or global developmental delays that could affect auditory processing were excluded.
- Left-handed children.
- Failure to meet any of the inclusion criteria during the pre-selection screening.

3.2.4 Test environment

The testing was conducted in the school premises. A quiet room was chosen as the testing location. The selected test room was located away from any noise sources. Testing was paused during interruptions like class changes, leisure activities, and lunch.

3.2.5 Instrumentation and Software

The following calibrated equipment was used

1. The Heine Mini 3000 LED otoscope was used for inspecting the ear canal and tympanic membrane.
2. Auditivo Micra Diagnostic audiometer with TDH 39 headphones conforming to ANSI S3.6 (2018) standards was used to obtain pure-tone air conduction thresholds.
3. A Behringer B2 Pro Dual diaphragm studio microphone with MOTU M2 audio interface was used for Audio recording of stimuli.
4. Adobe Audition version 2024 was used for recording, editing, noise reduction, and normalisation of speech stimuli.
5. MATLAB (Version R2014b) was used for RMS normalisation, stimulus calibration, SNR adjustment, and stereo presentation of dichotic stimuli
6. Asus Expertbook model number B1402CBA equipped with an Intel Core i7 processor was used for recording, digitisation and development of the Stimulus for Competing Sentence Test in Hindi.

7. Sony WH-CH720n over-the-ear headphone was used for stimulus delivery of the Competing Sentence Test.
8. Statistical Product and Social Sciences (SPSS) Version 26 (IBM Corporation, New York, USA) was utilised for statistical analyses.
9. Mendeley Reference Manager, was used for reference management.

3.2.6 Audiological Screening

3.2.6.1 Pure-tone Audiometry. For audiological screening purposes, the Auditivo Micra diagnostic audiometer with TDH 39 headphones was used. Subjective or biological calibration was performed each day, and a correction factor was applied before the start of the actual screening procedure. During the testing, the examiner instructed each child to respond by raising his/her hand to auditory stimuli presented through calibrated headphones. The children raised their respective hands every time he/she heard a tone, regardless of how soft or faint it was. The audiometric screening began with air-conduction testing at 1000 Hz, followed by 2000 Hz, 4000 Hz, and 500 Hz at a fixed screening intensity level of 20 dB HL. The child was marked as 'pass' if they responded to all four screening frequencies (500, 1000, 2000, and 4000 Hz). The child was marked as 'refer' if he/she did not respond to one or more frequencies in either ear.

3.2.6.2 The Screening Checklist for Auditory Processing (SCAP)(Mascarenhas, 2004). The checklist has 12 simple questions about the child's listening and learning behaviours. For every item, the respective teacher marked the response as either 'Yes' or 'No.' A score of 1 point was given for every 'Yes' response, and 0 points for every 'No' response. The scores for all items were summed to obtain a total score ranging from 0 to 12. A total score of 6 or below was considered a 'Pass,' indicating that the child was not at risk of (C)APD. A total score of 7 or above was considered a 'Refer,' suggesting that the child may be at risk for central auditory processing difficulties. Children who scored 6 or below on the SCAP checklist was included in the study, and those who scored 7 or above were excluded.

3.2.6.3 Speech Recognition Threshold. SRT assessment was conducted using a laptop running custom MATLAB code for stimulus presentation and response processing. Standardized digital spondee word lists were delivered via laptop headphones; MATLAB's Audio Toolbox facilitated audio playback and intensity control**.** Laptop volume was set to maximum, with software attenuation controlling levels from an initial 20 dB HL above PTA, descending in 10 dB steps and ascending in 5 dB steps descending-ascending method was used to present stimuli, with at least two spondees per level presented via MATLAB interface. Participant responses were recorded manually. The Speech Recognition Threshold (SRT) was defined as the lowest intensity level (in dB HL) at which the participant correctly identified at least 50% of the presented spondee words.

3.2.7 CST-H administration procedure

3.2.7.1 Calibration Procedure. Prior to testing, the output levels of the right and left channels were calibrated independently to ensure accurate dB HL -equivalent stimulus presentation levels. Channel-specific calibration was carried out using the KEMAR manikin by placing the headphone over the ears of the manikin, and the output was measured using a sound level meter. Channel-specific correction factors were incorporated within the MATLAB script to compensate for output differences between the transducers. A reference pressure of 20 µPa was used, and correction factors of -20 dB and -15 dB were applied for the right and left channels, respectively. The corrected intensity values were subsequently converted into linear amplitude factors for stimulus generation and presentation.

Children who passed all the screening criteria were included as participants in the next Phase III of the study to establish age-specific test scoring data. The finalised CST-H was administered using the MATLAB-based system through calibrated headphones.

3.2.7.2 Instructions. 'You will hear two different sentences at the same time, one in each ear. Your task is to listen carefully to the sentence in the target ear and ignore the sentence in the competing ear. You will then be asked to repeat the sentence from the target ear, and you are encouraged to guess if you are unsure. The same task will be repeated for the other ear in the same manner.'

3.2.7.3 Presentation Levels. The target sentence was played at 35 dB SL (ref. SRT), while the competing sentence at 50 dB SL (ref. SRT). This created a challenging signal-to-competition ratio of -15 dB, which was needed to test the binaural separation and avoid ceiling effects in performance.

3.2.7.4 Test Administration. The children were made to sit comfortably in the chairs, then instructions were given, and then headphones were placed on their ears. To make the child familiar with the testing procedure, 5 practice items were presented to each ear. The test comprised 30 sentence pairs, with 30 trials presented to each ear using a signal-to-noise ratio of -15 dB SPL. The primary message (target sentence) was presented at 35 dB SL in one ear (e.g., the right ear), while the competing message (competing sentence) was presented at 50 dB SL in the other ear (e.g., the left ear).

3.2.7.5 Scoring. The examiner scored each child's verbal response for every trial. Scoring focused on the number of pre-identified keywords that are repeated correctly from the target sentence. Each correct keyword was scored '1'. If the keyword was incorrect or could not be repeated, the score was given '0'. A total score was calculated for both the right-ear and left-ear target conditions.

3.2.8 Test-retest reliability

A subgroup of 20 children (50%) was selected with 5 children from each of the four groups, to examine test–retest reliability. Test–retest reliability assesses the stability and consistency of a measure over time by administering the same test to the same individuals at two different points in time. Establishing this form of reliability ensured that the CST-H produced dependable results that were not influenced by temporary factors such as chance, fatigue, or mood.

A follow-up session was scheduled 10 days after the initial assessment. This time frame is ideal because it provides sufficient time to reduce recall or practice effects, while remaining short enough to prevent meaningful changes in auditory processing skills. During the second session, the CST-H were re-administered using the same standardised procedure as in the first session. By comparing children' performances across sessions, the consistency of test outcomes could be evaluated, thereby establishing their reliability.

Figure 3.1

Flowchart Depicting the Step-by-Step Process of Stimulus Validation for the CST-H

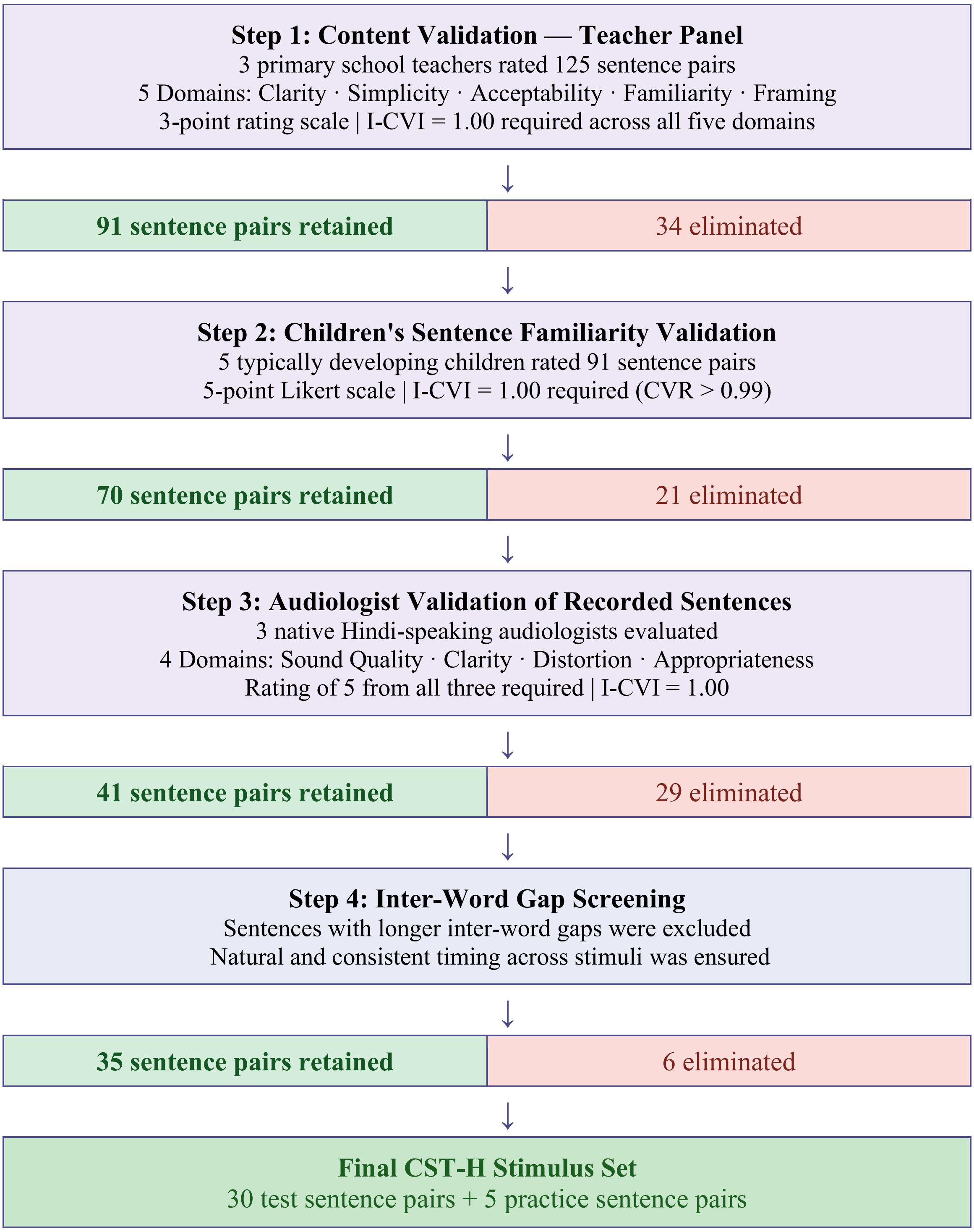
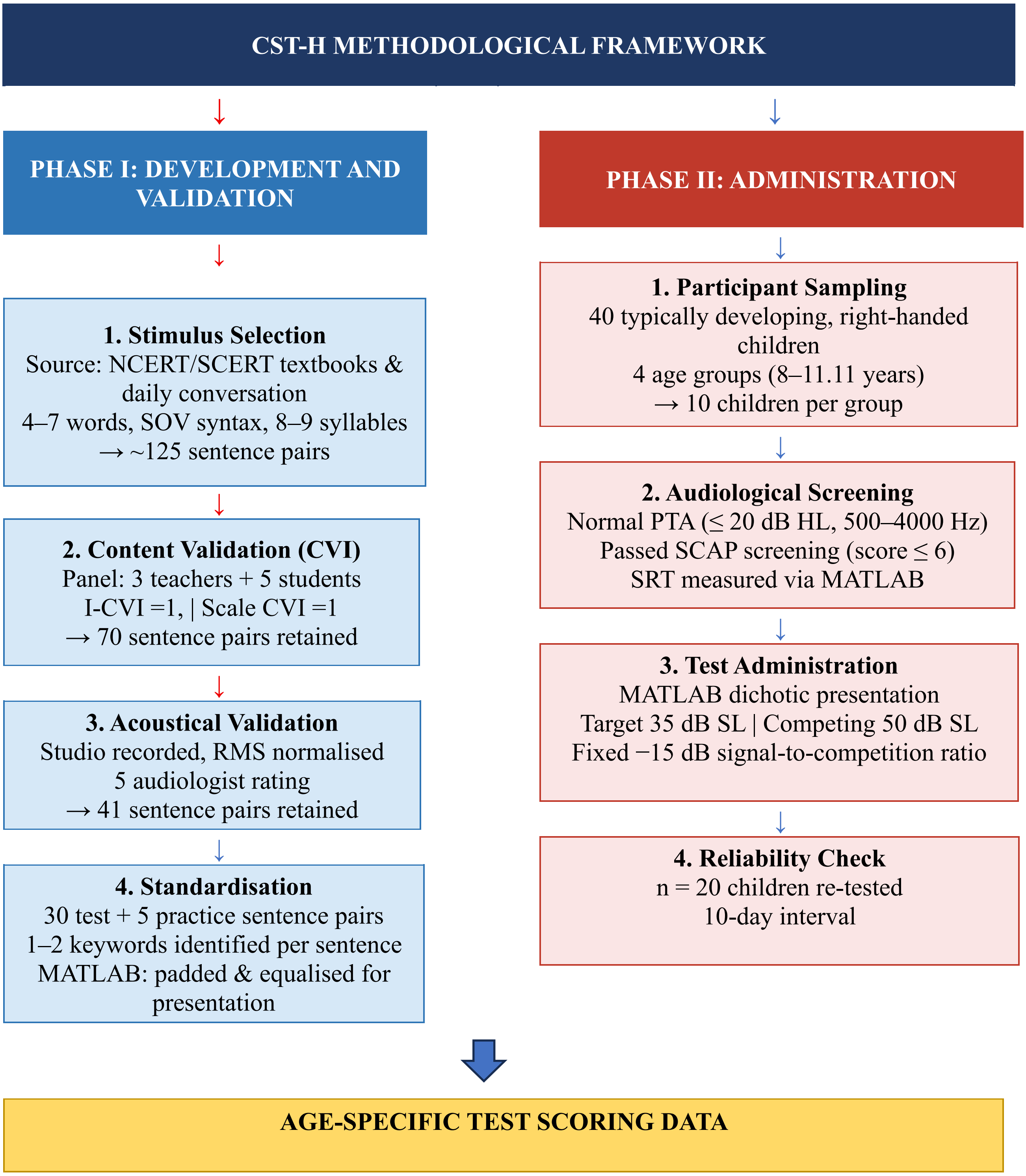


Figure 3.2

Procedural Flowchart for Phase I and Phase II of the CST-H



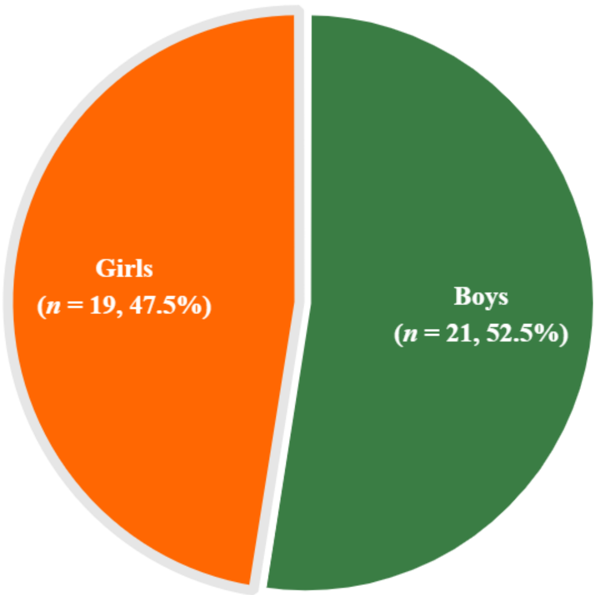
CHAPTER IV

RESULTS

The present study aimed to develop, validate and establish age-specific scoring data for the Competing Sentence Test in Hindi (CST-H), for children aged 8 to 11 years. A total of 40 typically developing, native Hindi-speaking children participated in the study. Participants were assigned to four groups with 10 participants each. Group 1 included children aged 8–8.11 years; Group 2, children aged 9–9.11 years; Group 3, children aged 10–10.11 years; and Group 4, children aged 11–11.11 years. The gender distribution of the study participants is given in Figure 4.1.

Figure 4.1

Gender Distribution of Study Participants



Note. The total number of participants is 40.

Statistical analysis was carried out using SPSS software. Before inferential statistical analysis, the data distributions were assessed for right-ear (RE) and left-ear (LE) scores across the groups using the Shapiro–Wilk test of normality. The results indicated that the majority of the dataset was non-normally distributed ($p < .05$). Therefore, non-parametric statistical tests were employed for subsequent analyses.

The following statistical procedures were carried out

- Descriptive statistics were applied to the data to obtain the median and interquartile range (IQR) for each age group and ear, as well as the mean and standard deviation (SD).
- Independent-samples Kruskal–Wallis H tests were performed on the data to examine the effect of age group on the right ear and left ear scores of the CST-H, with statistical significance set at $p < .05$. Post-hoc pairwise comparisons were done by using Dunn's test to check differences by comparing the age groups in pairs, with effect size reported as r.
- Wilcoxon signed-rank tests were performed to investigate the effect of ear on score and evaluate the difference between right and left ear scores within each age group.
- Spearman's rank-order correlation coefficients (r_s) were computed to check the test-retest reliability by comparing the right and left ear scores separately between two sessions. The strength of correlation is interpreted based on the r_s value.

4.1 Descriptive Statistics of CST-H Scores Across Age Groups and Ear

Descriptive statistics for CST-H scores by age group and ear are presented in Table 4.1. As shown in Table 4.1, the scores for the right ear (RE) and left ear (LE) improved with age. In other words, the median scores were lower for both RE and LE in Group 1 compared to Group 4. Within each age group, RE scores were higher than the LE scores.

Figure 4.2 shows the mean and standard deviation for the right ear and left ear datasets across age groups, with error bars representing ± 2 standard deviations. As illustrated, mean scores for both ears increased progressively with age. Children in Group 1 had the lowest mean scores for both RE and LE compared to those in Group 4. Within each age group, RE mean scores were consistently higher than LE mean scores.

Table 4.1

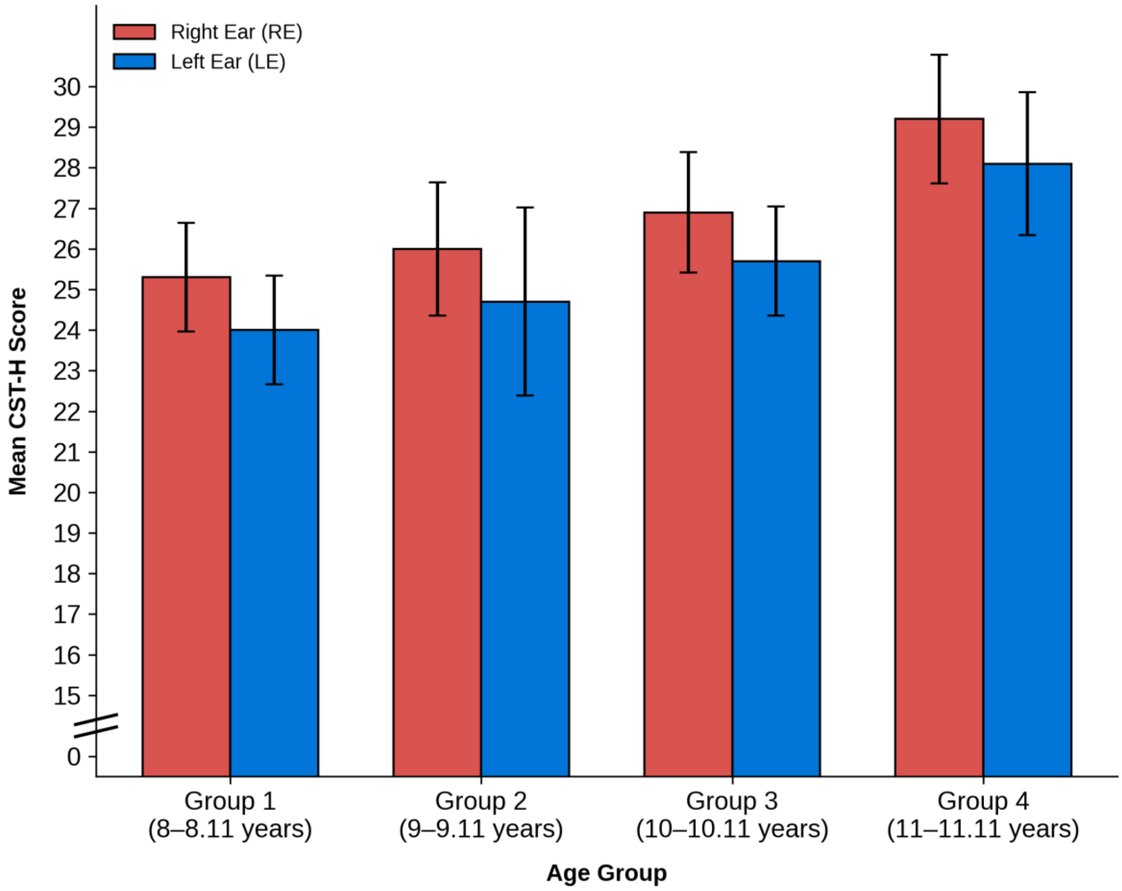
Median and Interquartile Range of CST-H Scores by Age Group and Ear

	Right Ear		Left Ear	
Age Group (n=10)	**Median**	**IQR**	**Median**	**IQR**
Group 1 (8–8.11 years)	25.00	1.00	24.00	0.00
Group 2 (9–9.11 years)	26.00	1.50	25.00	1.75
Group 3 (10–10.11 years)	27.00	0.75	26.00	1.00
Group 4 (11–11.11 years)	29.00	1.00	28.00	1.75

Note. IQR = interquartile range.

Figure 4.2

Mean Scores of CST-H for Right and Left Ears Across Age Groups



4.2 Age-Related Differences in Competing Sentence Test in Hindi (CST-H) Performance

Descriptive statistics for CST-H scores by age group and ear are presented in Table 4.1. There is an improvement in Score with increasing age across age groups from group 1(8-8.11 years) to group 4 (11-11.11years).

To examine whether CST-H scores differed significantly across the age groups, an independent-samples Kruskal–Wallis H test was conducted separately for RE and LE scores. The results revealed a statistically significant difference in right ear scores across the age groups, $x^2(3) = 29.742$, $p < .001$.

Post-hoc pairwise comparisons using Dunn's test indicated that differences in the right ear scores between Group 1 and Group 3 were statistically significant (p = .006, r= .611). Similarly, the scores between Group 1 and Group 4 (p < .001, r= 1), scores between Group 2 and Group 4 (p < .001, r= .885) and scores between Group 3 and Group 4 (p = .015, r= .543) were significantly different. All statistically significant pairwise comparisons demonstrated large effect sizes (r > .543; Cohen, 1988). However, the differences in scores between Group 1 and Group 2 (p = .230) and between Group 2 and Group 3 (p = .126) were not statistically significant. The test statistic, p-value, and effect size of pairwise comparisons are presented in Table 4.2.

Table 4.2

Pairwise Comparisons of Right Ear Scores Across Age Groups

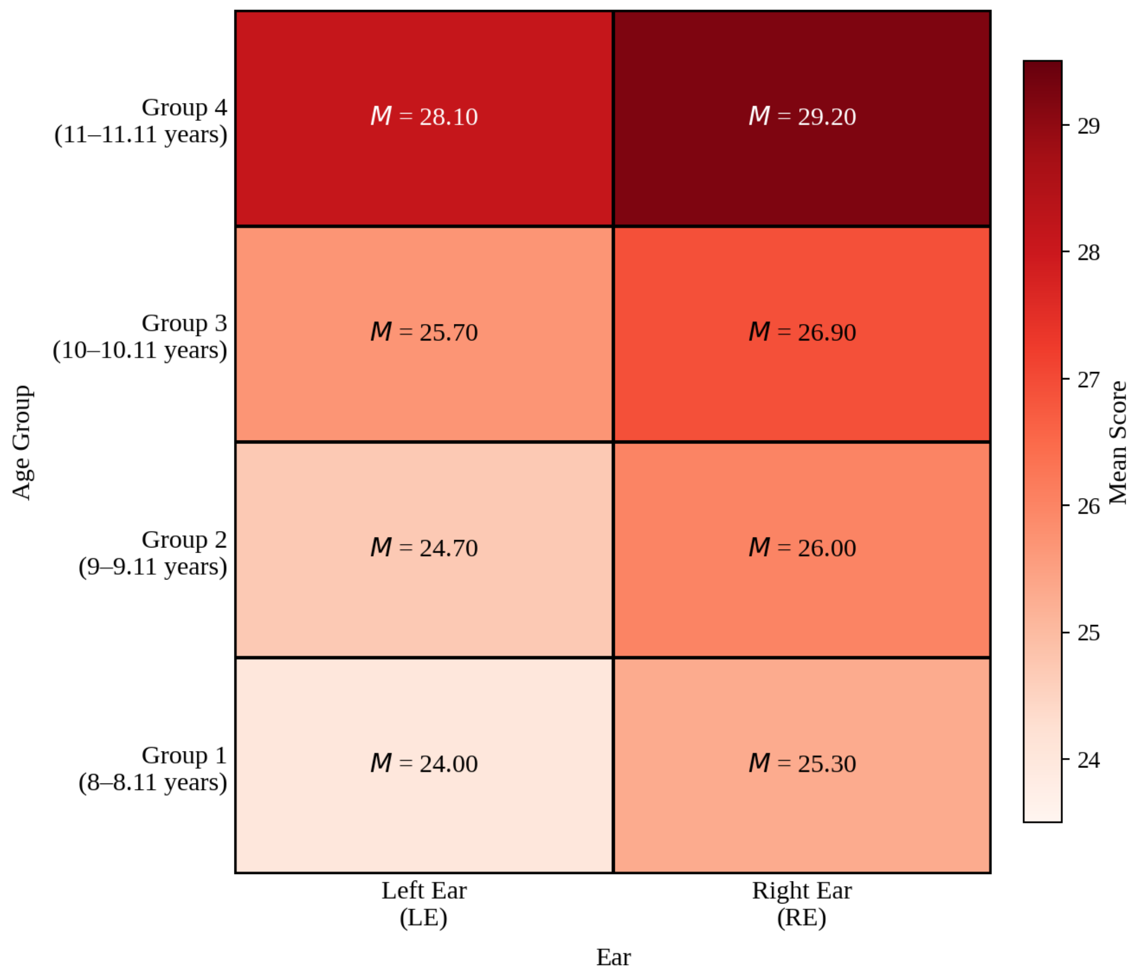
Comparison	**Test Statistic**	**Sig.**	**Effect Size (*r*)**
Group 1 vs. Group 2	-6.150	.230	-
Group 1 vs. Group 3	-14.000	.006	0.611
Group 1 vs. Group 4	-26.450	.000	1
Group 2 vs. Group 3	-7.850	.126	-
Group 2 vs. Group 4	-20.300	.000	0.886
Group 3 vs. Group 4	-12.450	.015	0.543

Note. The significance level is .05.

Similarly, left ear CST-H scores also revealed a statistically significant difference across the four age groups on independent-samples Kruskal–Wallis H test, $x^2(3) = 29.306$, $p < .001$. The improvement of the score across the age groups and ears is depicted in Figure 4.3.

Figure 4.3

Heat map representation of mean CST-H scores by age group and ear.



Note. Darker shades indicate higher mean CST-H scores

Post hoc pairwise comparisons Dunn's test indicated that differences in the left ear scores between Group 1 and Group 3 were statistically significant (*p* = .008, *r*= .595), with large effect size. Similarly, the scores between Group 1 and Group 4 (*p* < .001, *r*= 1), the scores between Group 2 and Group 4 (*p* < .001, *r*= .886), and the scores between Group 3 and Group 4 (*p* = .014, *r*= .549) were significantly different. All statistically significant pairwise comparisons demonstrated large effect sizes (*r* > .549; Cohen, 1988). However, the differences in scores between Group 1 and Group 2 (*p* = .248, *r*= .258) and between Group 2 and Group 3 (*p* = .132, *r*= .337) were not statistically significant. The test statistic, *p*-value, and effect size of pairwise comparisons are presented in Table 4.3.

Table 4.3

Pairwise Comparisons of Left Ear Scores Across Age Groups

Comparison	**Test Statistic**	**Sig.**	**Effect size (*r*)**
Group 1 vs. Group 2	-5.950	.248	-
Group 1 vs. Group 3	-13.700	.008	.595
Group 1 vs. Group 4	-26.350	.000	1
Group 2 vs. Group 3	-7.750	.132	-
Group 2 vs. Group 4	-20.400	.000	.886
Group 3 vs. Group 4	-12.650	.014	.549

Note. The significance level is .05.

4.3 Comparison Between Right-Ear and Left-Ear Performance

Median and Interquartile range are presented in Table 4.1. Right ear scores are better than the left ear scores across all the age groups.

A Wilcoxon signed-ranks test was conducted to compare right ear and left ear scores within each age group. Results revealed a statistically significant difference between right and left ear cores within all groups ($p < .05$), with the highest score in the right ear indicating right ear advantage. Test statistic and *p-values are* presented in Table 4.4.

Table 4.4

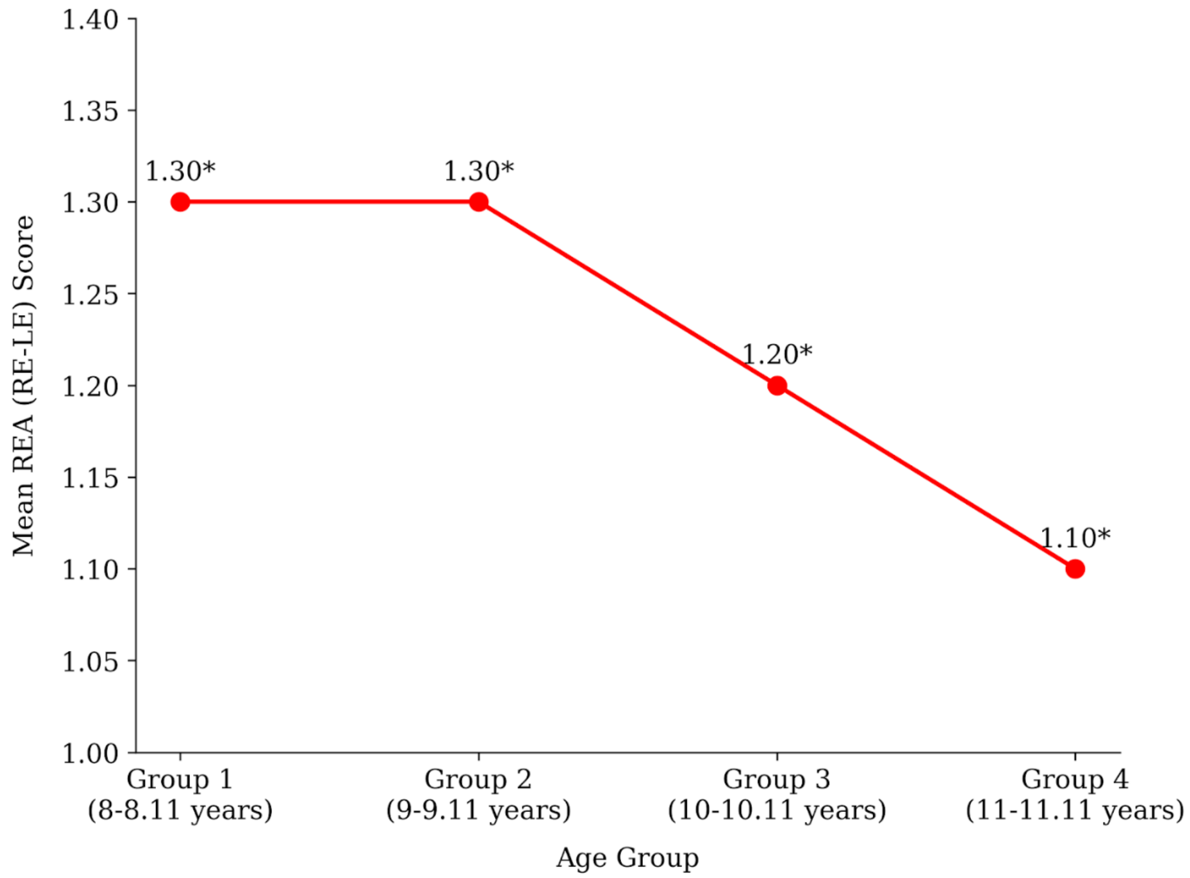
Within-Group Comparison of Right and Left Ear Scores Across Age Groups

Age Group	**|*Z*|**	***p* (2-tailed)**
Group 1 (8–8.11 years)	2.919	.004
Group 2 (9–9.11 years)	2.739	.006
Group 3 (10–10.11 years)	2.762	.006
Group 4 (11–11.11 years)	2.810	.005

Note. The significance level is .05.

Figure 4.4

Mean Right Ear Advantage (REA) Magnitude



Note. The significance level is .05.

4.4 Test–Retest Reliability of the Competing Sentence Test in Hindi (CST-H)

The test-retest reliability was assessed on 50% of the total participants (*n*= 20) and ensured the representation across the four groups. Age group classification was not considered while examining the test-retest reliability of the developed test, and participants from all age groups were combined for analysis. Spearman's rank-order correlation coefficient (r_s) was computed for scores obtained between two sessions. This was done separately for the right ear and left ear datasets.

The results indicated a strong and statistically significant correlation between the two test sessions. A very strong positive correlation was observed for both the right ear (*r*s = .866,

$p < .001$) and the left ear ($r_s = .870$, $p < .001$), indicating excellent consistency in test performance across repeated administrations and demonstrating high test-retest reliability of the developed test. Test statistic and *p-values are* presented in Table 4.5.

Table 4.5

Test-Retest Reliability of the CST-H for Right and Left Ear Scores

Condition	N	r_s	p
Right ear	20	.866	< .001
Left ear	20	.870	< .001

Note. The significance level is .05.

CHAPTER V

DISCUSSION

The present study aimed to develop the Competing Sentence Test in Hindi (CST-H) and establish age-specific normative data for children across four developmental age groups. The study addressed three primary objectives. First, it examined age-related changes in CST-H performance across the different age groups. Second, it investigated the presence of ear differences between right and left ear scores in the study population. Third, it evaluated the test-retest reliability of the CST-H to determine the consistency of performance across repeated administrations.

The findings show that CST-H scores improve across the age groups tested. The data also confirm differences in right and left ear scores and a strong test-retest reliability between test administration sessions. These results suggest that the CST-H has the potential to be a useful tool for the assessment of binaural separation in Hindi-speaking children.

5.1 Age-Related Differences in CST-H Performance

The findings of the present study show there is a statistically significant difference between the age groups for the ears, indicating that as the age increases, CST-H performance improves. The age-related improvements observed in the CST-H are consistent with developmental studies established in dichotic digit paradigms by Musiek (1983).

Research utilising the French Dichotic Digit Test demonstrated that performance across both ears improved significantly as a function of age. This improvement in function is directly associated with the age- related growth of auditory memory span and central executive functions in children aged 6 to 12 years (Jutras et al., 2012). Similarly, Lewandowska et al. (2023) confirmed this steady maturation in a Polish cohort. They reported that 7- and 8-year-old children showed relatively poor performance for both right and left ear. However, digit recognition scores increase progressively, reaching adult-like proficiency around age 12 to 13 years. Although dichotic digit tests assess binaural integration primarily rather than binaural separation, both tasks reflect the broader maturation of central auditory processing during childhood.

When examining dichotic listening using Consonant-Vowel (CV) syllables, as phonologically salient but semantically meaningless stimuli that place considerable top-down attentional demands on the listener. Moore et al. (2020) examined dichotic listening performance using CV syllables in children aged 6 to 13 years. Scores tended to increase with age, with children aged 11 to 13 performing relatively better than those aged 6 to 8. This indicates a gradual improvement in CV syllable processing across childhood, reflecting the progressive maturation of central auditory processing abilities, specifically dichotic paradigms.

The developmental pattern is also highly consistent with the literature focusing on dichotic word recognition. Kelley & Littenberg (2019) examined dichotic listening performance using the SCAN–3 Competing Words Test in children aged 7 to 14 years. Scores on the words test improved progressively with age across children aged 7 to 14 years. Similarly, Mattsson et al. (2018) demonstrated that performance on the competing words test improved significantly with age in a normative sample of 268 Norwegian children aged 7 to 12 years. Additionally, seven-year-old children showed the lowest scores and greatest inter-individual variability, and performance approaching ceiling levels in the oldest age groups. This indicates a gradual improvement in dichotic word processing across childhood, reflecting the progressive maturation of central auditory processing abilities.

The competing sentences test, developed by Lvey & Willeford (1988), consists of 30 pairs of sentences presented simultaneously to both ears and is appropriate for children aged 5 years and older. Normative data available for ages 5 through 10 years demonstrate that scores improve progressively with increasing age, reaching 100% in both ears by age 10.

Rhythm et al. (2024b) Further confirmed this developmental course in typically developing children aged 8 to 12 years, demonstrating a statistically significant effect of age on competing sentence scores, with children aged 8 to 10 years performing significantly lower than those aged 11 to 12 years, confirming the greatest improvement observed in the oldest age group. These findings of these studies indicate that competing sentence performance improves throughout childhood, reflecting the ongoing maturation of central auditory processing abilities underlying binaural separation.

Effective binaural separation places considerable demands on auditory attention, interhemispheric communication, and the suppression of competing acoustic signals (Bellis, 2003; Musiek & Chermak, 2014). These abilities continue to mature till late childhood. Musiek & Chermak (2014) highlighted that dichotic listening development is directly associated with maturation of higher-level auditory pathways and interhemispheric connections. A key neuroanatomical structure in this context is the corpus callosum, whose myelination continues through late childhood, with substantial maturation occurring around 11 to 12 years of age (Westerhausen & Hugdahl, 2008). Moncrieff (2011) observed that the maturation of dichotic listening performance across childhood depends on the ongoing development of the auditory cortex and corpus callosum. These abilities continue to integrate through late childhood and into early adolescence. Similarly, Reynard et al. (2023), assessed both binaural integration and binaural separation across a broad developmental range. They reported that dichotic processing improves as the central auditory pathways and myelination of callosal fibres of the corpus callosum mature. This neuroanatomical progress closely corresponds with the notably larger performance gain observed between the 8 to 8.11 years age group and the 11 to 11.11 years age group, suggesting that functional improvement of callosal pathways around this age is a key contributor to the observed age-related differences in competing-sentence performance.

On the other hand, though there were differences across the adjacent groups such as 8 to 8.11years and 9 to 9.11years, it did not reach statistical significance. The finding is consistent with the findings of Rhythm et al. (2024), reported no significant differences among 8 to 9.11 years. This lack of differences could be a result of to the lower sample size in each group. This pattern may reflect the gradual and cumulative nature of auditory maturation rather than an absence of development, suggesting meaningful changes in binaural processing may occur over broader developmental periods and may not be statistically detectable within single-year age intervals. In a cross-sectional investigation by Lewandowska et al. (2023) On central auditory processing maturation in children aged 7 to 16 years, reported that significant age effects on the dichotic digit test emerged primarily between groups separated by several years; the younger children performed comparably poorly to adjacent age groups but significantly more poorly than older cohorts. A similar pattern was reported by Jutras et al. (2012), who found that improvements in binaural integration on a dichotic digit task were most visible when children were compared across wider age spans of approximately three years, rather than across individual years.

The role of attention and linguistic processing in CST-H performance plays an important role. Unlike non-speech dichotic tasks, the CST-H presents meaningful sentence-level material, requiring the listener not only to segregate competing acoustic streams but also to engage in linguistic comprehension and selectively direct attention toward the target ear. For younger children, this dual demand — perceptual and linguistic — may increase the difficulty of the task beyond the ability of auditory maturation alone. Andersson et al.,(2008) demonstrated that children are considerably less effective than adults at deploying top-down attentional control under dichotic listening conditions, particularly when the demands of the task conflict with a naturally occurring stimulus-driven ear preference. The reduced capacity for volitional attentional modulation in younger children, as reported by Shinn et al. (2005), may have contributed to the lower scores observed in the 8–8.11 years and 9–9.11 years age groups in the present study. The gradual improvement in CST-H performance across age groups, therefore, likely reflects maturing of auditory processing, developing interhemispheric connectivity, and progressively more efficient cognitive and attentional regulation — all of which interact to support increasingly effective binaural separation in older children.

5.2 Comparison Between Right-Ear and Left-Ear Performance

The findings indicated a statistically significant Right-ear advantage (REA) for all four age groups in the present study. In every age group, right-ear scores exceeded left-ear scores. This finding is in close agreement with the foundational dichotic listening literature proposed by Kimura & Joseph (1966), who demonstrated that the REA for verbal stimuli reflects the predominance of contralateral auditory pathways and left-hemisphere specialisation for speech processing. According to Kimura’s structural model, auditory information presented to each ear is represented more efficiently in the contralateral hemisphere via dominant crossed auditory pathways. Consequently, linguistic stimuli presented to the right ear benefit from more direct and efficient access to the language-dominant left hemisphere for processing. The evidence presented by Kimura (1967) further demonstrated that asymmetrical functioning of the cerebral hemispheres is reflected in unequal perception of dichotically presented speech stimuli, resulting in right-ear superiority in individuals with left-hemisphere language dominance.

The competing sentence paradigm used in the present study places substantial demands on binaural separation and selective auditory attention. Under such conditions, hemispheric asymmetry becomes more apparent, thereby producing greater right-ear superiority. Subsequent dichotic listening research has consistently replicated these findings across different stimulus types and age groups. Specifically, Musiek (1983) noted that dichotic digit tasks consistently demonstrate right-ear superiority and reported that similar findings have also been observed for other speech stimuli in dichotic listening research. Collectively, these findings support the interpretation that the REA observed in the present study reflects normal hemispheric asymmetry for speech processing rather than a task-specific bias.

The persistence of the REA and its underlying structural mechanisms is heavily dependent on the functional integrity of interhemispheric auditory pathways, particularly the corpus callosum. Westerhausen & Hugdahl (2008) highlighted that the corpus callosum not only acts as a channel for the automatic exchange of information between the cerebral hemispheres but also allows for dynamic interaction in supporting both bottom-up and top-down stimulus processing. As maturation of the corpus callosum progresses during childhood, communication between the cerebral hemispheres becomes increasingly efficient, allowing left-ear information reaching the right hemisphere to be transferred more effectively to the language-dominant left hemisphere.

Although right-ear superiority remained stable across all age groups, developmental changes were observed in the magnitude of the interaural asymmetry. A gradual reduction in the REA with increasing age was observed based on within-group mean differences between right- and left-ear scores. While this reduction was not tested statistically, the trend reflects progressive maturation of interhemispheric transfer mechanisms during middle childhood and early adolescence. Moncrieff & Wilson (2009) similarly reported that performance improves with age across different digit conditions, especially in the left ear, which leads to smaller interaural asymmetries among older participants. Consequently, left-ear performance may improve at a relatively faster rate than right-ear performance during development, gradually narrowing the interaural gap. The persistence of REA across all age groups in the present study supports existing developmental literature on hemispheric lateralisation for speech processing.

The magnitude of the REA is dynamically influenced by the linguistic and cognitive complexity of the dichotic stimuli employed, which act as bottom-up modulators. Dichotic listening paradigms using consonant-vowel (CV) syllables, digits, words, and sentences differ substantially in their attentional, phonological, and linguistic demands, influencing both overall performance and the degree of interaural asymmetry. Mukari et al. (2006) stated that the magnitude of right-ear and left-ear scores, as well as REA, depends on the linguistic content of dichotic listening tests and generally increases with linguistic hierarchy.

Studies employing dichotic consonant-vowel syllables generally report strong and highly consistent REA effects because CV stimuli are brief, highly transient, and place substantial demands on rapid phonetic decoding. The cognitive and attentional factors (top-down modulators) also play an important role in this. Shinn et al. (2005) demonstrated that attention significantly influences the ear advantage during dichotic CV listening tasks. The REA increases when attention is directed toward the right ear and, in some cases, reverses to a left-ear advantage under forced-left attention conditions. Hugdahl & Westerhausen (2016) further justified this by illustrating how perceptual bottom-up factors interact with cognitive top-down factors, such as attention focus, to shape the asymmetry of auditory language information processing.

Word and digit-based dichotic listening tasks generally produce intermediate levels of REA; digits are highly familiar and overlearned stimuli with relatively low linguistic complexity, allowing easier binaural integration and recall. Musiek (1983) reported that dichotic digit tasks consistently produce right-ear advantages, although the degree of asymmetry was often smaller because digits impose comparatively lower phonological and linguistic processing demands. Similarly, Moncrieff (2006), using the competing words subtest of the SCAN test battery, demonstrated that competing-word paradigms are highly sensitive to interaural asymmetry and can reveal reduced left-ear performance in children with binaural integration difficulties.

. Jerger et al. (1968) shows that sentence-based materials provide a more realistic representation of ongoing speech processing than isolated words because they incorporate greater temporal and linguistic complexity. Shivashankar (1990) Similarly, it was noted that the CST utilises natural continuous sentences that closely approximate real conversational speech, increasing the linguistic and attentional demands placed on the listener.

Importantly, similar developmental and lateralisation patterns have been consistently reported across multiple linguistic populations. (Gósy & Krepsz, 2018) examined dichotic word recognition in Hungarian-speaking children and reported significant age-related improvement in dichotic listening performance along with persistent right-ear superiority. Recently, Rhythm et al. (2024)While developing and validating a Competing Sentence Test in Kannada (CST-K), researchers reported a statistically significant difference between scores obtained for the right and left ears, alongside significant age-related differences in binaural separation performance among school-aged children. Comparable findings have also been reported in Malay-speaking populations using dichotic digit paradigms, in French-speaking children using dichotic digit tasks and in Polish-speaking children assessed using dichotic digit paradigms (Jutras et al., 2012; Lewandowska et al., 2023; Mukari et al., 2006).

The convergence of findings across Hindi, Kannada, Hungarian, Malay, French, and Polish-speaking populations supports the neurobiological universality of hemispheric lateralisation for speech processing and the developmental maturation of binaural separation abilities, rather than pointing to language-specific effects. Collectively, the present findings align with extensive dichotic listening literature demonstrating that right-ear superiority and age-related improvements in competing speech performance are stable developmental phenomena. The consistent findings of these studies support the validity of the CST-H as a clinically relevant measure of binaural separation and central auditory processing abilities in Hindi-speaking children.

5.3 Test–Retest Reliability of the Competing Sentence Test in Hindi (CST-H)

The strong statistical significance of Spearman rank-order correlations obtained between the two test sessions for both ear conditions provides robust evidence of the test-retest reliability of the CST-H. The correlation coefficients exceeded the benchmark commonly recommended for clinically acceptable test-retest reliability in health-related measurement instruments (Portney & Watkins, 2015), suggesting that variability in an individual child's score upon re-testing doesn’t represent measurement error. The critical need for reliable dichotic measures in clinical populations was emphasised by Kelley & Littenberg (2019), who noted that establishing within-subject consistency across multiple administrations is essential to ensure that intra-individual variability does not confound the clinical diagnosis of auditory processing disorders. Furthermore, Ramachandran et al. (2023) demonstrated that well-constructed dichotic listening paradigms exhibit robust intra- and inter-session reliability, ensuring stable performance across repeated testing. This level of reliability is of direct clinical importance, as it indicates that a single administration of the CST-H yields scores that are stable and reproducible, thereby increasing confidence in clinical decisions based on the test.

The ten-day interval between test sessions was selected to balance two competing methodological concerns. Minimising the influence of procedural learning and stimulus-specific memory effects while avoiding the confounding influence of genuine developmental change in auditory processing ability over a longer period. This interval is consistent with contemporary psychometric research indicating that retest windows of one to two weeks are optimal for ability and executive functioning measures, as they are sufficient to reduce immediate recall of specific stimuli while avoiding genuine maturational change (Paap & Sawi, 2016). Furthermore, this timeline aligns with established retest procedures utilised in recent central auditory processing assessments, which standardise re-administration intervals of approximately one week for both paediatric populations (Tanaka et al., 2022) and adults (Ghosh & Nayaka, 2024). The high correlations between sessions, rather than a systematic upward shift in scores, further support the stability of the CST-H across repeated administrations and suggest the absence of a significant practice effect. No clinically meaningful differences in scores were observed between test and retest sessions, providing preliminary evidence against a significant practice effect.

The present findings contribute to the growing body of evidence that binaural separation, as assessed by competing-sentence paradigms, reflects the integrity of higher-order auditory processing pathways that are distinct from peripheral hearing sensitivity. All participants demonstrated normal peripheral audiological profiles, yet meaningful intergroup and interaural differences in CST-H performance, confirming that the test taps central rather than peripheral auditory function. This distinction is theoretically significant because it supports the view, articulated by Moore (2012) and Ahmmed et al. (2014), that listening difficulties in children with normal hearing thresholds frequently arise from deficits in top-down auditory processing, including selective attention, binaural integration, and figure-ground segregation, rather than from cochlear dysfunction. The CST-H, by employing a dichotic competing-speech paradigm, appears to engage precisely these higher-order mechanisms, making it a theoretically appropriate tool for identifying such difficulties in Hindi-speaking children.

CAPTER VI

SUMMARY AND CONCLUSION

The present study was undertaken to develop and validate the Competing Sentence Test in Hindi (CST-H), a language-appropriate measure of binaural separation for native Hindi-speaking children aged 8 to 11 years. Binaural separation allows to selectively attend to one ear while suppressing a competing message presented simultaneously to the other ear. Its accurate assessment requires normative data derived from a linguistically matched population. There is no such standardised tool for Hindi-speaking children, which represents a significant gap in audiological practice in India. The study sought to establish age-specific scoring data, document the right-ear advantage (REA), and evaluate test-retest reliability.

A total number of 40 participants (right-handed, native Hindi-speaking children) assigned to four age groups of 10 participants each (8–8.11, 9–9.11, 10–10.11, and 11–11.11 years) were recruited in the study. All participants underwent SCAP screening tests before participation in the study. All the participants had to respond to the stimuli conducted at a signal-to-competitor ratio of −15 dB using MATLAB-generated stimuli and calibrated headphones, with scores recorded as total keywords correct per ear (maximum 30). The Statistical analyses were performed in SPSS, using non-parametric procedures as the non-normality of the dataset was confirmed by the Shapiro–Wilk test of normality ($p > 0.05$).

Three principal findings emerged.

First, CST-H scores increased significantly and progressively with age for both ears, reflecting the ongoing maturation of central auditory pathways during this developmental period.

Second, a statistically significant right-ear advantage was observed, demonstrating consistent left-hemisphere dominance for speech processing across all four age groups.

Third, strong Spearman rank-order correlations between initial and re-administration scores for both ear conditions confirmed excellent test-retest reliability.

The CST-H demonstrated satisfactory psychometric properties and yielded age-differentiated, ear-asymmetric scoring of Hindi sentences.

Limitations of the Study

1. The use of a relatively small group of 40 participants may restrict the ability to generalise these findings to the broader, diverse Hindi-speaking population.
2. The use of only right-handed participants limits the generalizability of the findings to individuals who are left-handed or exhibit mixed-hand dominance.
3. The study lacks a direct comparison between the CST-H and other established binaural separation tools, which is necessary to fully confirm concurrent validity.

Implications of the Study

1. This research provides the standardised Competing Sentence Test – Hindi (CST-H) specifically designed for evaluating binaural separation skills in children.
2. Establishing clear scoring benchmarks for different age groups helps reduce misdiagnosis (false positives or negatives) caused by natural developmental variations.

Future Directions

1. It is essential to develop normative data for a wider age range, including younger children, adolescents, and the elderly. This can make the CST-H a more comprehensive diagnostic tool across the lifespan.

2. Investigating performance across different signal-to-noise ratios can provide a more detailed understanding of the performance of children at varying levels of environmental competition.
3. Establishing construct validity by comparing the CST-H with a broader range of central auditory tests will further strengthen its clinical utility.
4. The framework used here can be adapted to validate the CST in other major Indian languages, addressing the country's vast linguistic diversity.

Appendix 1

CST-H Sentence List

	Sl.	Target sentences	Competing sentences
Practice items	1	भाई चित्र बनाता है।	दोस्त पत्र लिख रहा है।
	2	छात्र गणित सीख रहे हैं।	बालक संगीत सीख रहे हैं।
	3	किसान खेत जोत रहा है।	माली बगीचा सींच रहा है।
	4	डाकिया संदेश लाता है।	मछुआरा मछली पकड़ता है।
	5	सुनार गहना बनाता है।	लोहार औज़ार बनाता है।
Test items	6	नाई बाल काटता है।	दर्जी कपड़ा सिलता है।
	7	भेड़ पहाड़ की चट्टान पर चढ़ रही है।	गिलहरी पेड़ की टहनी पर चढ़ रही है।
	8	बच्चा गाना गा रहा है।	युवक कविता पढ़ रहा है।
	9	पंडित मंदिर में रोज़ पूजा करते हैं।	भक्त रोज़ मंदिर में आरती करते हैं।
	10	यह हर दिन व्यायाम करता है।	वह रोज़ सुबह प्रार्थना करता है।
	11	राजा हर मंगलवार दरबार लगाता है।	सरपंच हर सोमवार पंचायत करता है।
	12	बूँद आसमान से धीरे-धीरे गिरती है।	ओस पत्तों से सुबह-सुबह टपकती है।
	13	मकड़ी दीवार पर जाला बुनती है।	चींटी ज़मीन के नीचे घर बनाती है।
	14	धोबी धुले हुए कपड़े बाहर सुखाता है।	काकी साफ़ परदे आँगन से उठाती है।

15	सूरज डूबते ही अंधेरा होने लगता है।	संध्या समय घर में दीपक जलाते हैं।
16	सोने से पहले हाथ-पैर धो लेने चाहिए।	सुबह उठकर बिस्तर ठीक कर देना चाहिए।
17	व्यायाम करने से शरीर मजबूत रहता है।	पौष्टिक खाने से सेहत अच्छी रहती है।
18	घर की सफ़ाई करना सब की जिम्मेदारी है।	कमरे में झाड़ू और पोंछा लगाना ज़रूरी है।
19	रोटी को तवे पर सेंका जाता है।	पराठे पर घी लगाकर परोसते हैं।
20	नियमित व्यायाम से शरीर स्वस्थ रहता है।	टीका लगवाने से बीमारी से बचाव होता है।
21	मेहमान उपहार लेकर आते हैं।	पड़ोसी दावत में सामिल होते हैं।
22	मुहल्ले के बच्चों के साथ खेलना मज़ेदार है।	छत पर पतंग उड़ाना आनंददायक होता है।
23	संगीत सीखने के लिए गुरु की ज़रूरत होती है।	नृत्य सीखने में निरंतर अभ्यास बहुत ज़रूरी है।
24	तालाब में मेंढक टर्र-टर्र करते हैं।	बारिश में केंचुए बाहर निकलते हैं।
25	पानी को गर्म करने पर भाप बनती है।	बर्फ पिघलने पर पानी बन जाती है।
26	उत्साहित होने पर ऊर्जा बढ़ जाती है।	थकान होने पर आराम करना चाहिए।
27	गणित सभी विषयों का आधार है।	विज्ञान तकनीकी ज्ञान देता है।
28	बल्ब से घर रोशन होता है।	पंखा गर्मी में ठंडक देता है।

29	मछली मांस का एक प्रकार है।	अंडा पोषक तत्वों से भरा है।
30	तूफान बहुत विनाशकारी होते हैं।	इंद्रधनुष बारिश के बाद दिखता है।
31	नीम का पेड़ औषधीय गुणों वाला है।	गुड़हल का फूल लाल रंग का होता है।
32	सम संख्या दो से विभाजित होती है।	अनंत की गणना नहीं की जा सकती है।
33	मित्रता स्वार्थ के बिना निभाई जाती है।	परिवार का बंधन जीवन भर रहता है।
34	पैसा कमाना जीवन की जरूरत है।	संतोष सबसे बड़ा सुख होता है।
35	शांति प्रयास के बिना नहीं संभव है।	सहयोग से कठिनाई आसान होती है।

Appendix 2

CST-H IPA Transcription

	Sl.	Target sentences	Competing sentences
Practice items	1	bʱa:i: tʃɪtr̩ bəna:ta: ɦɛ	do:st̪ pət̪r lɪkʰ rəɦa: ɦɛ
	2	tʃʰa:tr̩ gəɳɪt̪ si:kʰ rəɦe: ɦɛ̃	ba:lək səŋgi:t̪ si:kʰ rəɦe: ɦɛ̃
	3	kɪsa:n kʰe:t̪ dʒo:t̪ rəɦa: ɦɛ	ma:li: bəgi:tʃa: si:ntʃ rəɦa: ɦɛ
	4	ɖa:kɪja: sənd̪e:ʃ la:t̪a: ɦɛ	mətʃʰua:ra: mətʃʰli: pəkəɽt̪a: ɦɛ
	5	sʊna:r gəɦna: bəna:t̪a: ɦɛ	lo:ɦa:r ɔ:za:r bəna:t̪a: ɦɛ
Test items	6	na:i: ba:l ka:ʈt̪a: ɦɛ	d̪ərdʒi: kəpɽa: sɪlt̪a: ɦɛ
	7	bʱe:ɽ pəɦa:ɽ ki: tʃəʈʈa:n pər tʃəɽʱ rəɦi: ɦɛ	gɪlɦəri: pe:ɽ ki: ʈəɦni: pər tʃəɽʱ rəɦi: ɦɛ
	8	bətʃtʃa: ga:na: ga: rəɦa: ɦɛ	jʊvək kəvɪt̪a: pəɽʱ rəɦa: ɦɛ
	9	pəɳɖɪt̪ mənd̪ɪr mẽ: ro:z pu:dʒa: kərt̪e: ɦɛ̃	bʱəkt̪ ro:z mənd̪ɪr mẽ: a:rt̪i: kərt̪e: ɦɛ̃
	10	jəɦ ɦər d̪ɪn vja:ja:m kərt̪a: ɦɛ	vəɦ ro:z sʊbəɦ pra:rt̪ʰəna: kərt̪a: ɦɛ
	11	ra:dʒa: ɦər məŋgəlva:r d̪ərbɑ:r ləga:t̪a: ɦɛ	sərpəntʃ ɦər so:mva:r pəntʃa:jət̪ kərt̪a: ɦɛ
	12	bõ:d̪ a:sma:n se: d̪ʰi:re: d̪ʰi:re: gɪrt̪i: ɦɛ	o:s pət̪t̪õ: se: sʊbəɦ sʊbəɦ ʈəpkt̪i: ɦɛ
	13	məkəɽi: d̪i:va:r pər dʒa:la: bʊnt̪i: ɦɛ	tʃĩ:ʈi: zəmi:n ke: ni:tʃe: gʱər bəna:t̪i: ɦɛ
	14	d̪ʰo:bi: d̪ʰʊle: ɦʊe: kəpɽe: ba:ɦər sʊkʰa:t̪a: ɦɛ	ka:ki: sa:f pərd̪e: ã:gən se: ʊʈʰa:t̪i: ɦɛ
	15	su:rədʒ ɖu:bt̪e: ɦi: ənd̪ʰe:ra: ho:ne: ləgt̪a: ɦɛ	sənd̪ʰja: səməj gʱər mẽ: d̪i:pək dʒəla:t̪e: ɦɛ̃

16	so:ne: se: pəɦle: ɦa:t̪ʰ pɛ:r d̪ʰo: le:ne: tʃa:ɦɪe:	sʊbəɦ ʊʈʰkər bɪst̪ər ʈʰi:k kər d̪e:na: tʃa:ɦɪe:
17	vja:ja:m kərne: se: ʃəri:r mədʒbu:t̪ rəɦt̪a: ɦɛ	pɔ:ʂʈɪk kʰa:ne: se: se:ɦət̪ ətʃtʃʰi: rəɦt̪i: ɦɛ
18	gʱər ki: səfa:i: kərna: səb ki: dʒɪmme:d̪a:ri: ɦɛ	kəmre: mẽ: dʒʰa:ɽu: ɔ:r põ:tʃʰa: ləga:na: zəru:ri: ɦɛ
19	ro:ʈi: ko: t̪əve: pər sẽ:ka: dʒa:t̪a: ɦɛ	pəra:ʈʰe: pər gʱi: ləga:kər pəro:st̪e: ɦɛ̃
20	nɪjəmɪt̪ vja:ja:m se: ʃəri:r svəst̪ʰ rəɦt̪a: ɦɛ	ʈi:ka: ləgva:ne: se: bi:ma:ri: se: bətʃa:v ho:t̪a: ɦɛ
21	me:ɦma:n ʊpəɦa:r le:kər a:t̪e: ɦɛ̃	pəɽo:si: d̪a:vət̪ mẽ: ʃa:mɪl ho:t̪e: ɦɛ̃
22	mʊɦəlle: ke: bətʃtʃõ: ke: sa:t̪ʰ kʰe:lna: məze:d̪a:r ɦɛ	tʃʰət̪ pər pət̪əŋg ʊɽa:na: a:nənd̪d̪a:jək ho:t̪a: ɦɛ
23	səŋgi:t̪ si:kʰne: ke: lɪe: gʊru: ki: zəru:rət̪ ho:t̪i: ɦɛ	nr̩t̪jə si:kʰne: mẽ: nɪrənt̪ər əbʱja:s bəɦʊt̪ zəru:ri: ɦɛ
24	t̪a:la:b mẽ: mẽ:ɖʱək ʈərr ʈərr kərt̪e: ɦɛ̃	ba:rɪʃ mẽ: kẽ:tʃʊe: ba:ɦər nɪkəlt̪e: ɦɛ̃
25	pa:ni: ko: gərm kərne: pər bʱa:p bənt̪i: ɦɛ	bərf pɪgʱəlne: pər pa:ni: bən dʒa:t̪i: ɦɛ
26	ʊt̪sa:ɦɪt̪ ho:ne: pər u:rdʒa: bəɽʱ dʒa:t̪i: ɦɛ	t̪ʰəka:n ho:ne: pər a:ra:m kərna: tʃa:ɦɪe:
27	gəɳɪt̪ səbʱi: vɪʂəjõ: ka: a:d̪ʱa:r ɦɛ	vɪdʒɲa:n t̪əkni:ki: dʒɲa:n d̪e:t̪a: ɦɛ
28	bəlb se: gʱər ro:ʃən ho:t̪a: ɦɛ	pəŋkʰa: gərmi: mẽ: ʈʰəɳɖək d̪e:t̪a: ɦɛ
29	mətʃʰli: mã:s ka: e:k prəka:r ɦɛ	əɳɖa: po:ʂək t̪ət̪võ: se: bʱəra: ɦɛ
30	t̪u:fa:n bəɦʊt̪ vɪna:ʃka:ri: ho:t̪e: ɦɛ̃	ɪnd̪rəd̪ʱənʊʂ ba:rɪʃ ke: ba:d̪ d̪ɪkʰt̪a: ɦɛ

31	niːm kaː peːɽ ɔːʂəd̪ʱiːjə gʊɳõː vaːlaː ɦɛ	gʊɽɦəl kaː pʰuːl laːl rəŋ kaː hoːt̪aː ɦɛ
32	səm səŋkʰjaː d̪oː seː vɪbʱaːdʒɪt̪ hoːt̪iː ɦɛ	ənənt̪ kiː gəɳnaː nəɦĩː kiː dʒaː səkt̪iː ɦɛ
33	mɪt̪rət̪aː svaːrt̪ʰ keː bɪnaː nɪbʱaːiː dʒaːt̪iː ɦɛ	pərɪvaːr kaː bənd̪ʱən dʒiːvən bʱər rəɦt̪aː ɦɛ
34	pɛːsaː kəmaːnaː dʒiːvən kiː dʒəruːrət̪ ɦɛ	sənt̪oːʂ səbseː bəɽaː sʊkʰ hoːt̪aː ɦɛ
35	ʃaːnt̪iː prəjaːs keː bɪnaː nəɦĩː səmbʱəv ɦɛ	səɦjoːg seː kəʈʰɪnaːiː aːsaːn hoːt̪iː ɦɛ

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