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Speech sound errors in adolescents with congenital hearing loss

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Abstract

Children with hearing impairment (HI) often have vowel and consonant errors. Speech-language pathologists need this information to correct articulation errors. Despite the prevalence of research on speech sound error patterns in hearing aid users, there is a lack of literature in the adolescent group. The present study aimed to investigate the common speech sound errors in HI adolescents from the Malayalam-speaking community who have severe to profound hearing loss and are digital hearing aid users. A total of 15 monolingual Malayalam-speaking children between the ages of 9 and 16 years were recruited who had been diagnosed with speech sound disorders secondary to congenital hearing impairment. The minimum language age for inclusion in the study was over three years. Articulatory error analysis was performed for all consonants and vowels of the Malayalam language, and frequently produced vowel and consonant errors were included in the SODA and PMV analyses. The consonants frequently produced speech sound errors and no vowel errors were found. The most commonly produced consonant errors were fricatives, trills, laterals, velars, and alveolars. Substitution and omission errors were the most common type of error. Place and manner errors were more common than other types of errors. The results of this study may help parents and rehabilitation professionals to understand the common errors that persist even after intensive intervention. It may also be a useful guide for AAC therapists and speech-language pathologists in setting appropriate speech production goals for adolescents with HI.

Keywords: Adolescent; Hearing impairment; Vowels; Consonants; Articulatory error

1. Introduction

Congenital hearing loss is one of the most common birth defects to affect 2-3 in every 1000 births [1], the estimated prevalence of permanent bilateral hearing loss is 1.33 per 1,000 live births [2]. In children of primary school age, the prevalence increases to 2.83 per 1,000 children [3], [4] with a further increase to 3.5 per 1,000 in adolescents [2], which typically influences an individual's speech and language development [5] along with an impact on academic [6] and social skill development [7].

The development of oral language and speech production in children is facilitated only when there is normal or near-normal hearing in at least one ear. Verbal language perception, development, and usage are strongly related to the auditory sense. Therefore, even mild hearing loss can affect speech-language development in hearing-impaired children [8]. A child with bilateral hearing loss may be unable to hear spoken language and have difficulty developing intelligible speech [9]. In children with profound hearing loss, the natural acquisition of speech and spoken language is not often seen, unless suitable intervention is initiated early. Hence the intervention for children with hearing loss aims at fitting

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the amplification devices or cochlear implant at the earliest which improves the ease and the extent to which they can access and acquire speech and language skills [10].

The development of phonological representations that underlie spoken word production depends on the linguistic input received perceptually [11]. Several studies in the 1960s, 70s, and 80s described normal phonological development in terms of distinctive features [12], [13], [14], [15] The findings of these studies state that children can produce all the vowels and diphthongs by 3 years of age; by 7 years of age, children can produce all the phonemes except for the "/r/." By 8 years, the consonant blends are usually mastered, and overall speech production ability will be adult-like. When speech frequencies (i.e., 250-6000 Hz) become inaudible due to hearing loss in the high-frequency region where most consonants are located, speech becomes unintelligible and children will either misperceive conversational speech or may receive deteriorated and inconsistent signals (Svirsky, M. A., Robbins, A. M., Kirk, K. I., Pisoni, D. B., & Miyamoto, R. T. (2000).).

Literature suggests that children with hearing impairment (HI) are at greater risk of speech sound disorder (SSD) [17]. SSDs is a generic term used to describe a range of difficulties producing speech sounds in children [18]. Even though

the production of several phonemes (vowels and consonants) in isolation is accurate in children with hearing impairment, they find it challenging to coalesce these phonemes into connected speech, subsequently resulting in limited speech intelligibility [19].

Articulatory error pattern analysis in three to seven-year-old children with hearing loss reported a tendency towards vowel substitutions and consonant omission errors [19]. Comparing the speech sound production of hearing-impaired children, consonants versus vowels, vowel production has been reported to be better [20]. The acoustic and articulatory properties of the vowels derive from the relative ease of vowel production in children with hearing impairment; nevertheless, studies exploring the articulatory properties of vowels are sparse compared to their acoustic properties [21]. Predominantly substitution, omission, and distortion errors in vowel and consonant production are demonstrated by children with hearing impairment. Developmentally, these children fail to attain the 90% criterion for a majority of sounds other than vowels and some of the bilabial stop consonants [19]. Difficulties with speech sound production include problems with the articulation of vowels and consonants, such as substitutions, distortions, and omissions [22], [23], excessive use of a neutral vowel, such as schwa the unstressed vowel sound in the second syllable of the word "kitten" [24]; lack of adequate differentiation between various vowels [25], [26] and failure to differentiate between voiced and voiceless consonant sounds [27], [28]. This in turn results in a significantly slower rate of general speech sound awareness (phonological development) in children with hearing loss [29].

Aim and Objectives

The current study aimed to investigate the commonly produced speech sound errors in Malayalam speaking severely to profound hearing impaired (HI) adolescent children who used digital hearing aids. The specific objectives of the study were (a) to identify the frequently produced speech sound errors (consonants and vowels) in HI adolescents, and (b) to explain the type of errors based on substitution, omission, distortion, and addition (SODA) analyses in HI adolescents.

1.1. Need for the study

Despite the prevalence of research on speech sound error patterns in digital HA users, there is a dearth of literature in the adolescent age group. The accuracy and understandability of speech production can be increased if therapy is focused on correcting the speech sound errors that are most prevalent. In addition, the programming of amplification devices can be done more accurately and tailor-made to individual needs when frequently erroneous speech sounds are known.

2. Method

Participants: In the initial phase, 15 monolingual (5 males & 10 females) Malayalam-speaking-children between the age range of 9 to 16 years who had been diagnosed with spoken-language disorder secondary to congenital hearing impairment (>55 dB HL bilaterally) were considered for the study. The minimum receptive and expressive language age as the inclusion criteria of the study was set at greater than their years. All were attending speech-language therapy services,

All participants are digital hearing aid users who were binaurally programmed and fitted based on the configuration of hearing loss as certified by an audiologist. The aided audiometric thresholds of all participants were within the speech

spectrum. Children who were irregular hearing aid users/cochlear implants or associated/co-morbid conditions such as cognitive or motor deficits were excluded from the study.

All participants were regular digital hearing aid users. The participants were recruited by a simple random sampling technique. The study was approved by the Ethical Board of the institute. Each participant's parents provided written consent before the study, and there were no ethical challenges.

Procedure: The research followed a descriptive design. To confirm that all the participants had a minimum language age of three years, the Receptive-Expressive Emergent Language Test, Third Edition (REELS-3) by [30] was administered, it's a norm-based language test that examines the receptive and expressive language of children. Developmental Screening Test (DST), and another Indian norm-based test was used to rule out any cognitive, oro-motor, or motor impairments.

Articulatory assessment and transcription: Native speakers of Kerala in South India speak Malayalam language, a Dravidian language. It has 52 consonants and 11 monophthongs. All the vowels have minimal pairs and vowel length is phonemic. As in other Dravidian languages, the retroflex series includes subapical consonants, in which the tongue base contacts the roof. Additionally, three other varieties of retroflexes are there: lateral, trill, and nasal retroflex (ɭ, r, ɳ). Malayalam has fewer consonants in the word-final position.

Malayalam Articulation Test-Revised (MAT-R) a single-word articulation test by [31], was used to assess the articulatory skills of 15 participants using spontaneous repetition of 100 stimulus words which include vowels and consonants (vowels -10 and consonants in word-initial position - 26, consonants in word medial position- 28, consonants in word-final position - 05 and 31 clusters & blends) from the test. The examination took an average of 40 minutes to an hour to complete for each participant. The complete examination took place over one to two sittings for each participant to reduce fatigue and inattention. The recorded assessment sessions were listened to and transcriptions were made by using the International Phonetic Alphabet (IPA) by the authors.

The IPA is a set of speech sound symbols selected to represent the broadest variety of articulatory characteristics of consensus in all world languages (International Phonetic Association, 2005). The two types of transcription that we could use to transcribe a client's speech are narrow phonetic transcription and broad phonetic transcription [32], [33]. Broad phonetic transcription involves putting the sounds of the client's speech in brackets; narrow phonetic transcription involves special symbols or diacritics to further explain the client's speech.

The collected speech sample was evaluated in a range of situations. The vowel and consonant errors were analyzed and documented based on the 100 words (vowels and consonants in various word positions) taken from the test. The total number of errors for each participant was tailed for each vowel and consonant to identify the most frequently produced speech sound errors. Every stimulus word that results in the expected outcome phoneme error was given a score of '0', whereas a score of '1' was given for correct productions. This allowed for the calculation of each participant's percentage of errors for a specific phoneme

Qualitative analysis was done for the transcribed data. Each vowel and consonant underwent a separate qualitative analysis using place, manner, and voicing (PMV) as well as substitution, omission, distortion, and addition (SODA) error analysis, to ascertain the frequency of each type of error.

Vowels were qualitatively analyzed for articulatory errors in both short and long vowels. These errors are listed as follows: substitution errors where one vowel is substituted with another in replacement (e.g., in Malayalam language /pu:va/ for /pu:və/ where /a/ is substituted for /ə/, omission errors where deletion of one phoneme/syllable present (e.g., /teppə/ for /ʧeruppə/ where /u/ is omitted in the medial position), distortion errors are when a non-Malayalam sound is used to produce the target vowel and addition are when an addition sound to the target sound (e.g., /konnə/ for /onnə/, where /k/ is added in initial position). The percentage of errors was calculated for each vowel and vowel substitution errors were carefully examined.

Qualitative analysis of consonants: The SODA error number and percentage were calculated for every consonant. Following this PMV analysis was done to find the errors in place, manner, and voicing features to identify the consonant substitution errors. In word-initial and word-medial positions, consonant errors were analyzed under specific place and manner of articulation. Every percentage of phoneme substitutions as well as the particular phoneme that was substituted was noted. The overall percentage of substitution for each place of articulation (POA) and manner of articulation (MOA) was calculated. Following occurrences of the relevant phonemes, the percentage of voicing errors in word-initial and word-medial positions was also calculated.

3. Results

The descriptive analysis of articulatory errors made by the participants is discussed under two headings: frequently produced speech sound errors and type of errors of vowels and consonants.

3.1. Frequently produced speech sound errors

In MAT-R, vowels and consonants are assessed. There are more than twenty consonants assessed and five short & long vowels assessed. In that vowels are checked only in the initial position and consonants are checked in three different positions (initial, medial, and final). In the short and long vowel assessment, none of the participants made errors in vowel production both in isolation and the initial position of the word. However, there were speech sound errors in consonant production. The substitution errors are the most common, in that /s/ is the most commonly produced error sound, only 4 participants could produce the target sound correctly in the middle position of the target word /kasera/, however, there is no substitution error of /s/ in isolation and the initial position of the word. The sounds /g/, /ʂ/, and /b^h/ are the next commonly produced error sounds and out of 15 participants, a minimum of 2 participants produced substitution errors in these sounds. All these sounds have substitution errors in the initial position of the word. The sounds /g/ and /ʂ/ are produced correctly in isolation and the middle position of the word by all the 15 participants and /b^h/ is produced correctly in isolation by all the participants. The next least substitution error sounds are /ɽ/, /ɳ/, /ɲ/, /ɪ/, /ɽ/. The sounds/ɽ/, /ɲ/, /ɪ/ have errors in the initial position whereas the/ɳ/ sound has errors in the middle position.

The percentage of SODA errors was calculated for each consonant and it is given in the graph below, according to the position of the errors, in initial position /ʂ/, /g/, /b^h/, /ɽ/, /ɲ/, /ɪ/; in medial position /s/, /ɳ/. There were no errors in the final position at the word level.

3.1.1. Type of errors

Vowels: The vowels were analyzed based on SODA errors. There is no short vowel or long vowel errors in the speech sample both in isolation and word level in the initial positions in the MAT analysis of 15 participants in the study.

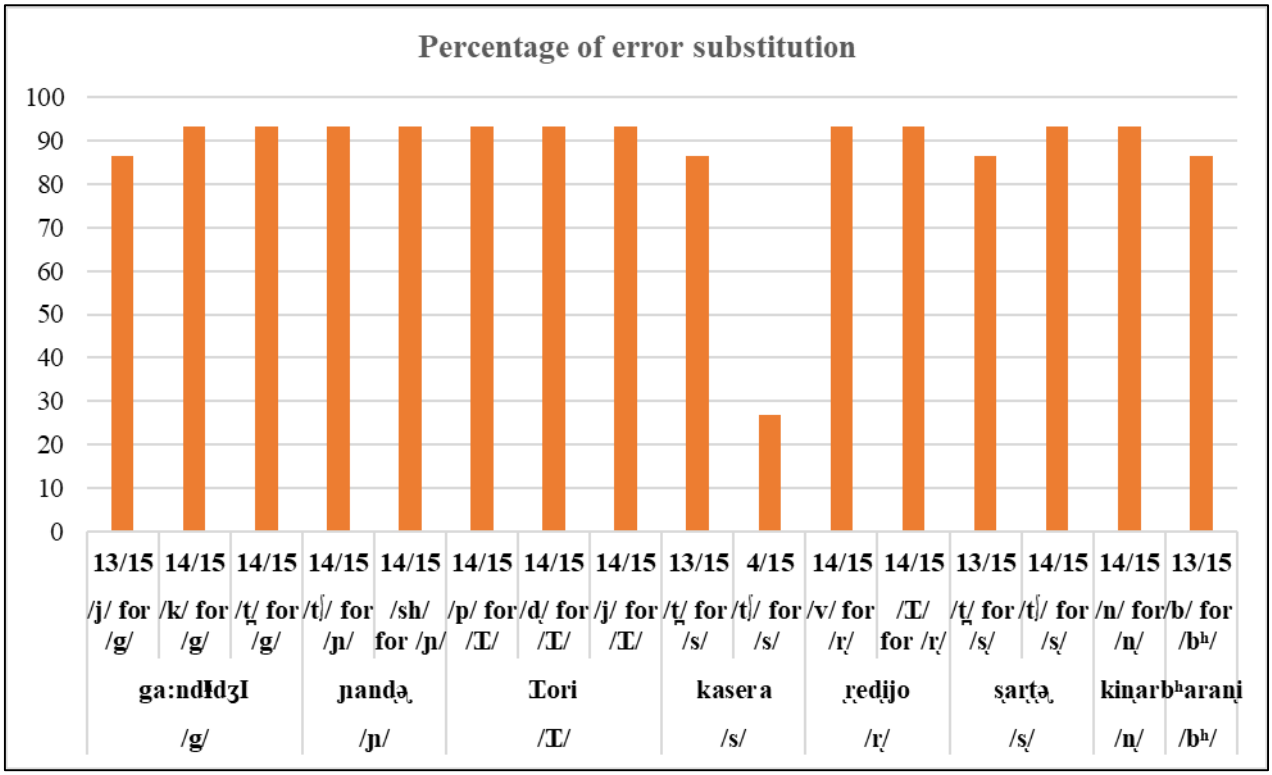
Consonant: Both SODA and PMV analyses were done for consonant errors. Only consonant substitutions were subjected to the PMV analysis, to determine the specific error types.

3.2. SODA Analysis

In SODA error analysis, only substitution and omission errors are observed and there were no addition and distortion errors seen in the articulatory analysis.

The consonants that have substitution errors are /s/, /ʂ/, /g/, /b^h/, /ɽ/, /ɳ/, /ɲ/, /ɪ/. The detailed error analysis is given in the figure 1 & figure 2.

The consonants /ɲ/, /ɪ/, /ɽ/are produced correctly by 93.33% of the participants in initial position; /b^h/ is produced correctly by 86.66% of the participants in initial position; /g/ is produced accurately by 73.33 % of the participants in the initial position and /ʂ/ is produced correctly by only 33.33% of the participants in the initial position, and these are substitution errors. The speech sound /s/ has omission errors in the initial position and was produced correctly only by 86.66% of participants. In the medial position /dʒ/ and /ɳ/ are produced by 93.33% of participants correctly and these speech sounds have substitution errors; /k/ and /ɽ/ have omission errors in the medial position and are produced by 86.66% of participants correctly.



(x-axis – substituted error sound, y-axis – percentage of error)

Figure 1 Percentage of substitution errors for consonants

3.3. PMV analysis

The substitution errors were subjected to PMV analysis, wherein errors were classified as P (place error); M (manner error); V (voicing error); PM (place and manner error); PV (place and voicing error); and PMV (place, manner, and voicing error) depending on their frequency of occurrence.

Velar stop /g/

At the initial position, the voiced velar stop /g/ showed place and manner errors, and devoicing errors (/k/ for /g/) were observed. For the velar stop /g/, the substitution with alveolar stop /ʈ/ and palatal approximant /j/ was the most common error observed. This could be a coarticulation effect or inherent ease of production due to anterior placement in the/ʈ/ sound.

Retroflex nasal (/ɳ/)

/ɳ/ is classified as palatal nasal by [33], [34], [35], [36], [37]. Predominant errors were seen in the initial position. Alveolar for retroflex was the most commonly occurring place error.

Retroflex trill (/r/)

Mostly place and manner errors were observed for /r/ in the initial position, dental for retroflex was the main place error whereas stop for trill was the major manner error. The most common error was substitution with voiced labiodental approximant and dental lateral.

Alveolar fricative (/s/)

Place and manner errors were observed more for /s/ at the initial position. Labiodental approximant and alveolar lateral were the most common types of errors observed.

Alveolar lateral /l/

Place and manner errors were observed more for alveolar lateral approximant /l/ in the initial

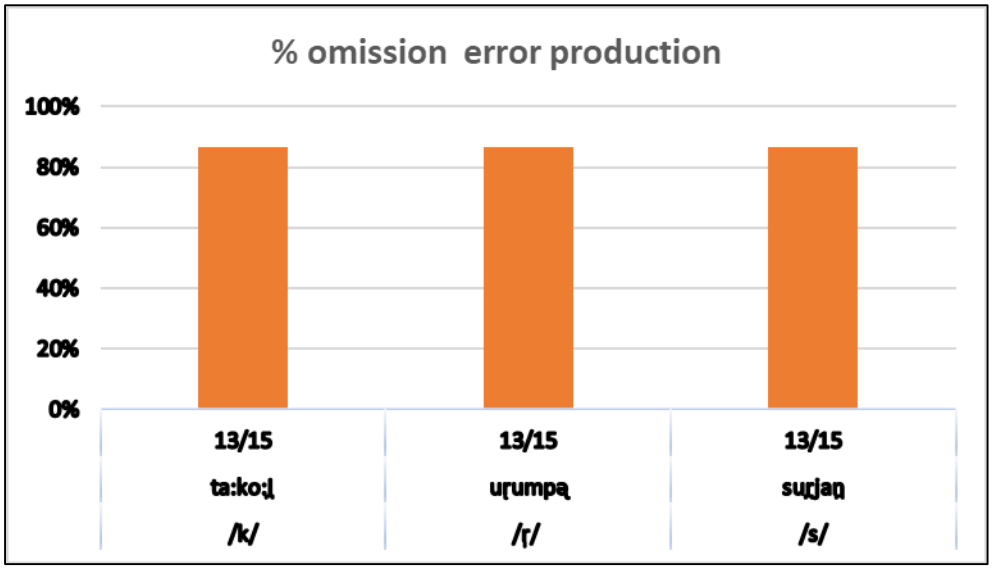
position of the word. The substitution is by labial plosive and retroflex plosive.

Retroflex fricative (/ʂ/)

Place and manner errors were more common in the word-initial position for /ʂ/. Dental plosive and palatal plosive were the common types of substitution in the initial position.

Retroflex palatal /ɳ/

Place and manner errors were observed, alveolar nasal /n/ is substituted for /ɳ/.



(x-axis – omission error sound, y-axis – percentage of error)

Figure 2 Percentage of omission errors for consonants

Overall, it can be concluded that the dental place of articulation is predominantly replaced by alveolar, retroflex, palatal, and velar place of articulation in the speech of HI children. Stops were primarily substituted in place of affricates, fricatives, trills, and laterals when the manner of articulation was considered. Stops /g/ were frequently noted to have devoicing errors. Errors of place and manner, and errors alone predominated over the errors in word-initial position. Substitution errors are commonly in the initial position and omission errors are more in the middle position of the word.

4. Discussion

Ideally, HI children are continuously supported with suitable Has to provide them the chance to access sounds and spoken language. The main goal of this study was to pinpoint the speech sound errors in vowels and consonants of Malayalam-speaking HI children using digital HAs. The vowel sounds are produced correctly; both short and long vowels. This finding is different from other studies where they noted short and long vowel errors, this discrepancy in results could be attributed to the familiarity with the stimulus and the language. Additionally, older children were chosen for the trial study and every participant had received long-term speech and language therapy. Children with HI might have been able to perceive and produce temporal cues as a result of this.

Given that vowels do not require as much precision in their articulatory positions as consonants do, the present findings are consistent with the existing literature in that consonants exhibit more frequent speech sound errors [20], [37]. According to Jakobson's (1941) structuralist model of phonological acquisition, children differentiate vowels before consonants. Later, place differences and nasal/oral consonants contrast merged. In our study, consonants that are frequently misarticulated were in the order /s/, /ʂ/, /g/, /bʰ/, /ɾ/, /ɳ/, /ɲ/, /ɪ/ and /k/ are speech sound errors more observed than other classes of speech sounds. The higher occurrence of the above-mentioned error sounds is attributed

to the complex articulation required (especially sounds like /r/, and/s/), perceptual difficulties, or the temporal characteristics which have been reported in acoustic studies [38].

The frequent error productions of the fricatives /s/ and /ṣ/ in children with HI may be attributed to the perceptual difficulties of fricatives as a result of the higher frequency composition of these sounds, which makes it difficult for hearing aids to pick these sounds [39]. In other words, children with HI are deprived of high-frequency acoustic cues due to their inability to hear them, which causes them to have trouble producing fricatives. Recent research reveals perceptual difficulties in children with SSD which is correlated with that of HI children [40].

The literature suggests that children with HI tend to frequently exhibit substitution errors [19]. Similar findings were shown in the current study, with children who use digital HA showing increased substitution errors than omission errors. However, the errors reported in the current study are comparably less than the other research. The positive impact of long-term speech and language therapy regularly for the hearing-impaired population before the recruitment in the current study might have contributed to this difference in findings.

Additionally, the current research shows that errors of place of articulation are more common than errors of manner and voicing. Due to their improved visibility and anterior positioning, dental sounds frequently replaced other places of articulation [41], [42]. Substitution errors are mostly described in the word-initial position [43]. The current study findings revealed substitution errors mainly in the word-initial position which supports the above concept. In terms of the manner of articulation errors, substitution using front sounds was more prevalent, which is consistent with findings by [44]. According to Wiggin M, et al., (2013) research on the emergence of consonants in young children with HI, this can be attributed to the early acquisition of front sounds. Their inherent ease of production due to anterior placement could be another potential explanation.

The results of the current study also showed that there were fewer devoicing errors for various classes of speech sounds than had been previously reported in the literature [37], [45], which indicates the HI population overcame the difficulty in mastering differentiation between voiced and unvoiced cognates during long term intensive speech-language therapy as it is the late acquired feature in speech acquisition [46].

The findings of this study can help parents and rehabilitation professionals understand the common errors that persist even after a long time of intervention. As a result, it can be a helpful guide for audio-verbal therapists and speech-language professionals for developing suitable speech production goals for children with HI. In addition, it may be a sign of poor prognosis if a child is not making progress toward the speech production goals. In addition, combining the knowledge about the frequently produced error sounds and the frequency composition of different sounds will aid the audiologist in providing adequate gain at different frequency bands during hearing aid programming.

The findings also suggest that the duration of therapy is an important factor for professionals to consider, to understand the probable speech sound errors the individual can make, and also audiologist can identify frequency regions that require higher gain.

Only a small number of studies have looked at the articulation and phonological skills of children with HI, and the current study is one among the few that have done so. The improvement of speech production skills is a crucial area of attention in intervention since they have an impact on speech indelibility and communication competence.

Limitations of the present research include a small sample population of unequal numbers of females and males which fails to explain the gender-specific differences in speech sound errors. Since the current study suggests the influence of therapy duration on speech intelligibility, future studies can focus on different durations of therapy which can improve the intelligibility tremendously. This can be used as a counseling tip for parents. Future research can also consider a larger sample size and in other Indian languages.

5. Conclusion

An investigation of fifteen children with HI who used digital hearing aids was done as part of the current study to describe articulatory errors. Samples of speech were offline transcribed. The articulation therapy for children with HI ideally focuses on misarticulations to help them acquire speech sound productions and enhance their speech intelligibility. The current study emphasized common consonant and vowel errors made by Malayalam speech HI adolescent children who are digital HA users.

Compliance with ethical standards

Disclosure of conflict of interest

The authors declare that there are no conflicts of interest regarding the publication of this article.

Statement of ethical approval

The current study received ethical approval from the Institute's Ethical Committee. We strictly adhered to ethical protocols while conducting this study.

Statement of informed consent

Informed consent was obtained from all individual participants included in the study.

Authors' contributions

The first and second authors conceptualized the study and designed the methodology. The third author conducted the data analysis. The second author wrote the original draft, while the first author reviewed and edited the manuscript.

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