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Aspects of Vowels Analysis for Speech & Hearing Diagnostics

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Vowels in Kannada Conversational Corpora of Congenital SNHL with Contemporary Hearing Devices Encompass both Articulatory Competency, and Misarticulation Variability of Vowels, I – An Introductory Report

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Abstract

This study is on vowel articulation competency in conversational speech corpora of heterogeneous types of congenital bilateral sensorineural hearing loss (SNHL) participants who had undergone long-term comprehensive aural oral speech and language therapy (LT-CAOSLT). Vowel competency and its connection to types of hearing devices in use is compared A Perceptual judgment approach is adapted for a large recorded speech corpora after the administration of the test TELS HI in Kannada. Vowel competency differed across three hearing –domains (D): analogue behind the ear hearing aid users, digital programmable hearing aid users and the cochlear implanted (D1, D2 and D3). Domain1 demonstrated significant remnants of vowel defects with an exception of a high frequency sensorineural hearing loss participant in D 1 who showed 100% vowel competency. Further, only one of three similar D2, and four out of six D3 demonstrated100% vowel competency .The vowel disordered participants showed both articulatory capability of all vowels and large tokens of variable misarticulated vowels in their speech corpora. Alarmingly, there was not a single vowel which showed 100 % vowel articulation competency in this second group even after LT-CAOSLT.

Keywords: vowel, articulation, residual ,congenital Sensorineural hearing loss , speech corpora , conversation, disorder, analogue behind the ear hearing aid ,programmable digital behind the ear hearing aid ,cochlear implant ,competency , therapy ,phonetics, variability , random

Introduction

Irreversible sensorineural hearing loss (SNHL) at birth affects speech and language acquisition. Sensorineural hearing loss (SNHL) is due to disorders involving either inner ear or auditory nerve, or both (fig 1). The identified congenital SNHL infants; toddlers and children are intervened with hearing device and intensive long-term speech language therapy. Three main types of hearing devices are currently in use for hearing rehabilitation in congenital SNHL population in India. They are the analogue behind the ear hearing aids, the digital hearing behind the ear hearing aids and the cochlear implantations (figs .3, 4, 5). For the sake of this study, the SNHL with these hearing device types are termed as hearing domains D1, D2, and D3 respectively. Devices of D0 (analogue body level hearing aid fig2) and D1 type are yet of relentless use for many geographical, social ,economic and health care reasons as stated in Gayathri (2016). Research in articulation disorders in congenital SNHL has spanned nearly 85 years. The studies have incorporated either the perceptual or the acoustic methods or both. Even though, the number of vowels are lesser in number than consonants in Kannada, they together bear a higher proportion of frequency of occurrence in Kannada. The vowel segments account for 40 to 50% frequency of occurrence in Kannada (Ranganatha1982; Sreedevi, Smitha, & Vikas 2012; Ratna, Gopal & Gayathri 1978). Thus, due to their plentiful nature and as carriers of speech in addition, they have significant functional role in speech communication. For these reasons stated here, the efficacy of vowel articulation is a critical issue in communication tasks which is investigated in the present study.

Figure 1. Affected parts of the ear in irreversible congenital SNHL.


Figure 2.domain 0,D0, analogue body level hearing aid

Figure 3: domain 1,D1, analogue behind the ear hearing aids

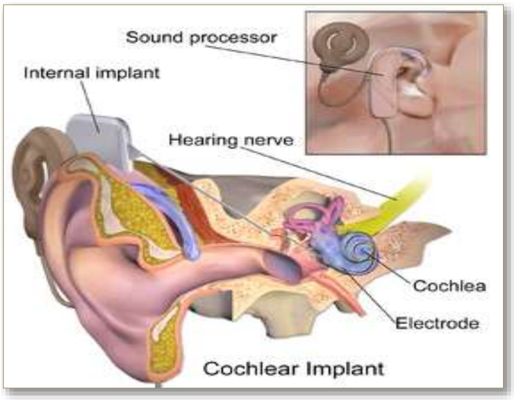

Figure 4: domain 2,D2 programmable digital behind the ear hearing aids

Rawlings (1934), Voelker (1937), Heider, Heider, Sykes (1941); Hudgins & Numbers (1942);

Figure 5: Domain 3,D3 the Cochlear Implanted

Hudgins (1934), Numbers (1936) were the pioneers to report vowel articulation defects in congenital SNHL. At that time, analogue body level hearing aids (D0) were in use. Perceptual studies of vowel articulation disorders in congenital SNHL have identified the conventional misarticulations of substitution, omission, distortion and addition patterns types (Carr, 1953, West & Weber 1973, Nober 1967, Smith 1975, Mangan 1961, Ling1976, Geffner 1980, Pratt and Tye-Murray 2008). However, other vowel articulation disorder patterns are also identified. These can be summarized under four reported categories. Firstly, is centralization of vowels (Hudgins & Numbers 1942, Boone 1966, Markides 1970, Ling 1976, Levitt, Smith, Stromberg &Gold 1980; Angelocci, Kopp & Holbrook 1964; Smith 1975). Secondly, is error of longer vowel duration than target vowels (Monsen, 1974, Osberger & Levitt 1979, Thirumalai & Gayathri 1982, 1988; Ryalls & Larouche 1992, Clement, Koopmans-van, Louis1996; Uchanski & Geers 2003; Ramadevi 2006, Gayathri 2016). Thirdly, is the vowel diphthongization defect, wherein a single target vowel segment turns out to become a combination of double vowel element (Markides 1970, Ling 1976, Levitt, Smith & Stromberg 1976; Gayathri 2016). Lastly, the nasalizations of vowels (Ling 1976, Ramadevi 2006, Svirsky1998, Hudgins & Numbers 1942 Boone 1966, Numbers, Jr 1936, Brannon 1966, Fletcher & Daly 1976, Gayathri 2016) are mentioned in the literature.

Classic presentations for strong footholds of early identification of congenital SNHL in the context of critical period for speech and language developments began in 1970s which are seen in Lenneberg (1967), Downs & Northern (1974). It became evident with successive studies that early identification of congenital SNHL through implementation of high risk registers, universal new born hearing screenings, early hearing and speech rehabilitation result in greater benefits in terms of speech language development.. Naturally, with this back drop and with the modern contemporary inventions in the west, the D2 and D3, participants in research in latter two groups are generally far younger than in the time span of analogue hearing aid users in the west and in this study. In addition, literature in speech characteristics of cochlear implant population is larger than that of digital BTE hearing aid users. No separate mention is made in later research studies regarding D0, D1 or D2, rather the term conventional hearing aids came into use.

Now, proceeding to hearing Domain 3, documentation of emergence of vowel sounds followed post operatively following the pre implantation baseline vowel and other segmental phonetic inventories. Diversity of vowels, longitudinal studies of vowels, description of nature of vowel segments , accuracy of vowels, speech intelligibility have been the focus of research (Kirk & Hill-Brown 1985, Tye-Murray & Kirk 1993 , Osberger, Robbins, Todd, Riley, & Miyamoto 1994.; Ertmer 2001; Ertmer et al. 2002, , Adi-Bensaid & Tobin 2010, Dawson, Blamey, Dettman, Rowland, Barker, Tobey, Busby, Cowan & Clark 1995, Tobey, Geers, & Brenner1994, Boothroyd , Geers, Moog & Jean 1991; Geers & Brenner 1994; Miyamoto, Osberger, Mary Joe, Robbins, Myres & Kathy 1993 ; Ertmer, , Kirk, Sehgal, Riley & Osberger 1997; Tobey & Geer 1995; Osberger, Robbin, Todd, Riley, & Miyamoto1994, Perkell, Lane, Svirsky & Webster 1992; Andrea , Davis & Morrison 2008; Serry & Blamey 1999; Seifert ,Oswald , Bruns , Vischer , Kompis & Haeusler 2002) in pre and post cochlear implantation in D3 studies .

In addition, comparative studies of speech segments between different hearing devices also began to appear in the literature. Miyamoto, Kirk, Robbins, Todd & Riley (1996); Osberger, Maso & Sam (1993); Ertmer, et al (1997); Tobey et al (1994) were some of the investigators have compared the efficiency of different hearing devices for vowels and speech segmental productions. The primarily fine grained audibility with practical implications (Boothroyd et al 1991, Boothroyd1997) and speech perception skills were coupled for assessments with efficacies in speech production in D3 (Ertmer, et al 1997, Tye-Murray, Spencer & Gilbert-Bedia 1995).

While, **a** large body of literature has explored presence or absence of vowel defects, the primary focus of a few other investigators is comparisons of vowel articulation performances between different hearing statuses. Severity and type of hearing loss were primary parameters for articulation comparisons in many investigations (Markides1970; Gayathri1983, 2016; Baudonck, Van Lierde, Dhooge & Corthals2011; Osberger, Maso, & Sam 1993; Stelmachowicz, Pittman, Hoover, Lewis & Moeller 2004; Verhoeven, Hide, Maeyer & Gillis 2016). Vowel Articulation and speech comparisons with hearing device on and off and comparison of speech between SNHL and normal hearing were other dimensions in studies of articulation in SNHL. . Some others have adapted developmental vowel articulation assessments and their comparisons in SNHL. Articulation performances of two different types of congenital SNHL patterns of analogue body level hearing aid users were compared in Kannada with multiple types of vowel articulation defects in bilateral profound congenital SNHL and total absence of vowel defects in congenital high frequency SNHL (Gayathri 2016). Both were analogue body level hearing aid users, termed as domain 0 in this paper (see figure 2).

Noteworthy updated reviews and discussions on vowels in SNHL can be found in works of Ling (1976), Osberger & Mc Garr (1982), Geers (1997), Svirsky (1998) and Thirumalai & Gayathri (1988). Kato & Yoshino (1988); Monsen, (1978); Monsen (1983); Osberger & Levitt (1979) ; Sfakianaki, Nicolaidis, & Okalidou (2016) ; Metz, Samar, Schiavetti, Sitler & Whitehead (1985); Massen & Povel (1985)and Gold (1980) are some researchers who have focused on the intelligibility in the deaf speech with conventional hearing aids. Gold 's (1980) serious concern with analogue body level hearing aid users was that only about 20% of the speech output of the deaf is understood by the "person-on-the-street" .On the other hand , in subsequent research in domain 3, the cochlear implanted can be seen drifting from gross phonetic deviations to fine grained approximations to target phonetic behaviors of speech.

In this, diverse context of ongoing speech production studies in congenital SNHL the question raised in current study is on vowel competency in a structured natural communication context in D1, D2 and D3. If they have 100%, vowel articulation competencies after the completion of LT-CAOSLT in spoken communication context. . Conversational database of three hearing domain types is also examined to identify any tendency for vowel – specificity in the 100% articulation competence.

Methods

A qualitative and perceptual approach is designed for this ongoing study. The purpose of this study was to obtain three different sets of conversational speech corpora from corresponding hearing domains: D1, D2, and D3 by administering a section TELS HI/Kannada. An incidental participant sampling which involved accessibility of participants, several criteria and multi factors listed below resulted in heterogeneous population of congenital SNHL with three different hearing devices.

1. Subject selection

The primary criteria for selection of subjects included 10 primary parameters. 1. All subjects had congenital bilateral symmetrical SNHL 2 all subjects had cleared ENT and clinical examination for certifying normal speech mechanism. Tonsillitis and adenoiditis (T and A), deviated nasal septum (DNS), and obscure sub mucous cleft were also ruled out through clinical examination. 3. They had normal IQ 4. They had undergone comprehensive long-term aural oral speech therapy(LT-CAOSLT) in Kannada. That means that they either had completed speech therapy or had completed at least 7 years of speech language therapy .5. Their mother tongue and regional tongue is Kannada 7. They wore one of the hearing devices in D1, D2 or were cochlear implanted, D3. 8. They were integrated to normal schools 9. They had normal hearing parents and siblings who spoke Kannada at home. 10. They had consented speech recording for the parent study. In general, adult female SNHL resented to be participants for this study .This resulted in Incidental Heterogeneous sampling. Finally, a total of 18 subjects (6 female and 12 male) were incidentally selected (tabe1) . The resulting sample contained residents of Karnataka from Mysore, Bangalore, Tumkur, Chikkaballapur, Ramnagar, Kollegal, Chamrajnagar, Nelmangala, and Bidadi. Each participant was classified on the bases routine the severity and type of SNHL pattern (Katz 2002) and specific device use. Table 1 depicts the clinical parametric details and distribution of 18 SNHL participants in this study. The Cochlear implanted were bilinguals in Kannada and English even though speech language therapy was initiated in Kannada. Two participants of D1 types were second congenital SNHL sibling in family, labeled as sib2. These are marked with grey row in the table (table 1). Only Two participants were continuing therapy, marked in pink rows. However, they had undergone long-term therapy for at least 7years, marked in pink rows in this table . . All others had completed speech and language therapy. Under the D1 group were also the early identified two participants at age 6 and 8 months.

2. Descriptive alpha numeral participant coding:

Every subject was labeled with an alpha numeral encapsulated coding system. Basic routine core -conventional -clinical constrictions was adapted for this study for reader friendly purpose. This contained degree and type of SNHL (e.g. psn=profound SNHL). Additional clinical descriptions of device use (D1, D2, D3), child(C) or adult (A), sibling two (sib2) were also encapsulated in coding. Table1 also provides expansion of reader friendly subject coding for e.g. ApsnD1 =adult profound SNHL with domain 1 device, Aspsib2D1 = adult severe profound SNHL with domain 1 device and second congenital SNHL child in the family etc. Thus, essential descriptions of every participant were encapsulated in reader friendly coding method. All these clinical details of participants are tabulated in table 1.

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3. The rapport sessions for speech sampling.

Each participant reported for the recording in a healthy condition. Recording was avoided and postponed if the participant had fever, cold or cough. The participant faced the clinician across a working table in a silent room. Two initial sessions were rapport sessions for acclimatization to the context. Care was taken so that no part of the speech language test tool, or tasks similar to the tool was conducted in first two sessions. Recordings of these initial rapport sessions were not analyzed for this study.

Table 1. Clinical details and subject coding of D1.D2,D3 participants in this study. n=18

Aural Oral Speech Therapy since age	**Age @ data collection**	**Expansion of subject coding**	subject	Table 1 – details of participants with congenital SNHL All are bilaterally symmetrical D1= analogue behind the ear hearing aid user, n=9 D2 =programmable digital BTE user,n=3 D3= cochlear Implanted [UL],n=6 n=18
4 y, 1/12	17y11/12	Adult profound D1	ApD1	
No1-3 y,2/12 No2- at 6 months	22y,2/12 18y,7/12	Adult severe profound D1 2 subjects	AspD1	
4y,5/12	19y,7/12	Adult moderate severe D1	AmsD 1	
5y,8/12	19y,1/12	Adult high frequency D1	AhfD1	
No1 – 2 y,9 /12,33/2 No2 - 3y, No3-4 , 10	18y,1/12,20y 27y,10/12	Adult severe profound D2	AspD2	
3y ,4 /12 2y,8/12 2 y, 1/12 3 y 3 y1/12 2y,5 /12	9 y 8 y1/12 9 y 5//2 10y, 4/12 9y, 7/12 9 y, 3/12, 10y, 5 /12	4 profound 2 severe profound =6 cochlear implanted. Sampling Criteria after 4-5years post speech and language therapy ; D3	D3	
3y,1/12	11y, 7 /12	Child profound D1	CpD1	
4y,2 /12	11 y,4 /12	Child moderate severe D1	cmsD1	
8months	19 y	Adult profound sib2D1	Apsib 2D1	
1 y,4/12	19 y, 3 /12	Adult severe profound sib2D1	Asp sib2D	

Language	Therapy
Word ,phrases , simple sent s.	Completed
Word, phrases partial, complete sent s.	Completed
- " -	Completed
Complete sent s. Fluent.	Completed
Complete sent s, Fluent.	Completed
Complete sent s. Fluent	Completed
Word ,phrases	for 7years - ongoing
Word , phrases	for 7years - ongoing
Word .phrases	Completed
Word, phrases, simple sent s.	Completed

4. Administration of TELS- HI and Recording of dyadic conversation for data generation

The participant was administered sections 12.3 and 12.4 coined after clinical use as *Test for the Evaluation of Language and Speech of the Hearing Impaired in Kannada: TELS – HI /Kan* developed at Central Institute of Indian Languages, Mysore (Thirumalai and Gayathri 1980-82, 1988, and 1994. See Appendix 1 in monograph). This test is applied for clinical use since 1982. Dyadic conversation was recorded on alternate days in successive sessions. Each session ran a stretch of a maximum of 40minutes. The clinician made notes in her diary as the recording and testing were in progress. From these dyadic tasks were generated natural speech corpora for each participant. Hence, multiple phonetic and co articulation contexts in the spontaneous utterances participant were captured at data generation. Audio recording was performed in all test sessions with digital SONY high quality audio recorder with high quality microphone.. Number of total recording per participant ranged from 9, 4 and 2 sessions. Where possible and when the subject found the conversation contexts interesting prompts were applied at recording to elicit larger speech corpus.

5. Transcription

Transcription was performed by the clinician in sound treated Audiology room with head phones connected to the recording device at Bangalore. The recording was first played two to three times for familiarization and later fine transcriptions were done of defective speech units. IPA transcription was adapted with fine attributions wherever needed. Core unit at transcription was phon, placed within its contextual word unit marked by square brackets. Words in turn showed either isolated occurrence or they were parts of phrases, sentences and stretch of utterance. Three sets of conversational speech corpora were generated as databases from 18 participants. They comprised D1, D2 and D3 groups. Every participant's transcription profile was also maintained separately.

6. Analyses

Phonetic inventory of Kannada language has 10 vowels (Upadhaya, 1972).The transcribed conversational speech corpus was examined in each participant to identify those vowels which were acquired with 100% articulation competency. When all10 vowels in participant's corpus showed this achievement, then that participant demonstrated 100% vowel articulation competence. In rest of the participants, the data searching was done to identify those vowels, which showed 100% competency and those vowels which did not show 100% vowel competency. Attempt was made to examine if a specific vowel was influencing vowel articulation competency in a participant or in a group as a whole. These results are compared across the three different hearing domains.

Results

Table2. SNHL participants who were 100% competent in vowel articulation =(√)

ApD1	AspD1	AmsD1	AhfD1	AspD2	D3	CpsD1	CmssD1	Apsib2D1	Aspsib2D1
-	-	-	√	√ No3 n=3	√ 4/6	-	-	-	-

This study is unique in that it is a first attempt to study large natural speech corpora in congenital SNHL participants in Kannada. Results from analyses are presented under the following headings below. In general, not all participants in D1, D2 or D3 groups, who had completed LT-CAOSLT with their respective hearing devices, showed vowel articulation competence at conversation in the current study. Results are described under the following sections.

1.100% vowel articulation competencies–

. One high frequency SNHL analogue behind the ear hearing aid user (AhifsnD1), one severe profound SNHL programmable digital BTE user, AspsnD2; and four cochlear implanted participants showed 100% vowel competency at conversation(Table 2). Vowels in these participants were thus error- free in natural conversational task of TELSHI/Kannada.

Nevertheless, in 12 other congenital SNHL participants it was evident that even though, they either had completed LT-CAOSLT vowel errors sustained in their speech corpora. They were obstinate residues in their spoken conversation. Table 2 represents the results of vowel competency achievements in congenital SNHL.. Pattern of SNHL contributed to differences in vowel competency achievement in D1 users, with hifSNHLD1 standing as exception to the general trend of persistent vowel defects in D1. In D2 users, even though three participants were of severe profound SNHL type only one of two exhibited vowel articulation competency .Both of these participants had completed speech and language therapy. D3 users as a group had achieved vowel articulation competency with exceptions of minimal or sporadic vowel nasalization in their speech corpus in two participants. All sib2D1 participants showed vowel defects. They had completed speech and language therapy programme. In addition, all child participants who were undergoing speech and language therapy at the time of study continued to show vowel defects in their speech corpora.

1. Exploration of vowel specificity for 100% competency in 12 other participants

The data bases were examined to see if competency existed for specific vowels in those participants who lacked 100% vowel articulation competency. However, none of ten Kannada vowels showed a tendency for 100% vowel articulation competency in these participants. Hence, vowel specificity for 100% vowel articulation competency was not found. Their conversational repertoire contained both normal vowel articulation and defective vowel articulation of all vowels. More often, the vowels were found misarticulated in multiple manners in theory speech corpora. Thus, their speech corpora contained variable representations of same vowel in addition to their normal vowel articulation capability.

2. Comparison of three hearing domains for vowel competency

As a group, none of the hearing domains can be denoted with 100% articulation competency. No definite statements can be made in D2 or D3 users. This is because, participants in this domain showed trends for either 100% vowel articulation competency or the converse. In general, most analogue behind the ear hearing users in D1, show vowel defects. Exception to this exposition is seen in high frequency SNHLD1. These results are similar to earlier findings with analogue body level hearing aid users, D0 (Gayathri 2016, Gayathri1982). Thus, pattern of SNHL is contributing parameter to vowel competency could be deduced only in D1. In D1 users, even the participants with lesser degree of hearing loss, the adult moderate severe SNHL who had completed speech language therapy and child moderate SNHL who had undergone 7 years of speech language therapy did not show 100% vowel competency (Figure 7).

3.1. The D2 Group did not however contain any hifSNHL participant.

3.2. Two adult severe profound SNHL in D2 domain did not present 100% vowel competency. Exception in D2 group was one D2 user out of three, who demonstrated 100% vowel competency. All of them also had completed long term speech and language therapy.

3.3. One D2 participant shows a unique or atypical speech pattern .His speech alternates in bits in a recurring manner with misarticulated vowel segments in one type of speech-bit and completely normal segments in other type of alternating speech bit . This type of vowel variability is not reported in hearing impaired literature.

3.4. In D3 are seen only sporadic vowel misarticulations in only two participants .The other four show 100% vowel competency .They are hence superior as a group compared D1 and D2 in general .

3. **Total number of years of long term comprehensive speech and language therapy (LT-CAOSLT) and 100% vowel competency**.

The D3 users had completed LT-CAOSLT in only 3-5 years. Yet, they showed efficiency in vowel articulation than D1 users and D2 users who had undergone LT-CAOSLT for as long as 7 to 18 years. However, they had shown a trend for persistence of vowel disorders. Thus, total number of years of therapy was not directly related to the acquisitions of vowel competence in congenital SNHL. In addition, both D1 participants who had completed the intensive long term speech and language therapy and those who were still continuing (7years +) the therapy showed vowel defects in general.

4. Another interesting observation in this study is that of an early identification and clinically intervened participant under D1. Hearing Domain1 contains a participant who was identified at 6 months with congenital bilateral severe profound SNHL. However, due to poor economic status of parents at the time of her identification she was fitted with analogue behind the ear hearing aid instead of D2 device use.D3 intervention was not available at the time of her intervention. Even though, she had undergone nearly 18 years of LT-CAOSLT with D1 she displayed residual vowel defects. This is in striking contrast with performance of D3 as a group. The D3 were identified for SNHL as late as two years compared to this AspD1 participant. Hence, early identification of SNHL in the critical period combated with inefficient traditional D1 auditory device is not successful for acquisition of vowel competence at conversation. Similar findings are seen in second sibling with severe profound SNHL who was diagnosed at 8 months and fitted with a D1 device. This participant was yet undergoing speech and language therapy at the time of data collection.

5. **Vowel variability**

At the data searching of vowels in the speech corpora variability of vowels is a prominent characteristic identified in the current study. There are not only inter subject vowel variability within the group but also intra subject variable vowel tokens for same vowel.

5.1. For example, the following examples depict variable vowel articulations along with normal articulation for vowel [a] in two subjects in D1.

E.g. 1 . a, a< , a~ , a> , A, AA, AA>, A>, e>, e~ , E” , E”>, EE ,e<”, A”> , I> , **ou<**

E.g.2. : a, A, A>, ae , a~ , e , o< , o, U.

5.2. The vowel variability range from sporadic, episodic, minimal, moderate to severe degree.

5.3. The variability of vowels is sometimes solitary .But, more often they were represented in multiple phonetic forms (Gayathri, 2019).

5.4. The complexity of variable vowels in speech corpora are embedded from simple to complex phonetic forms

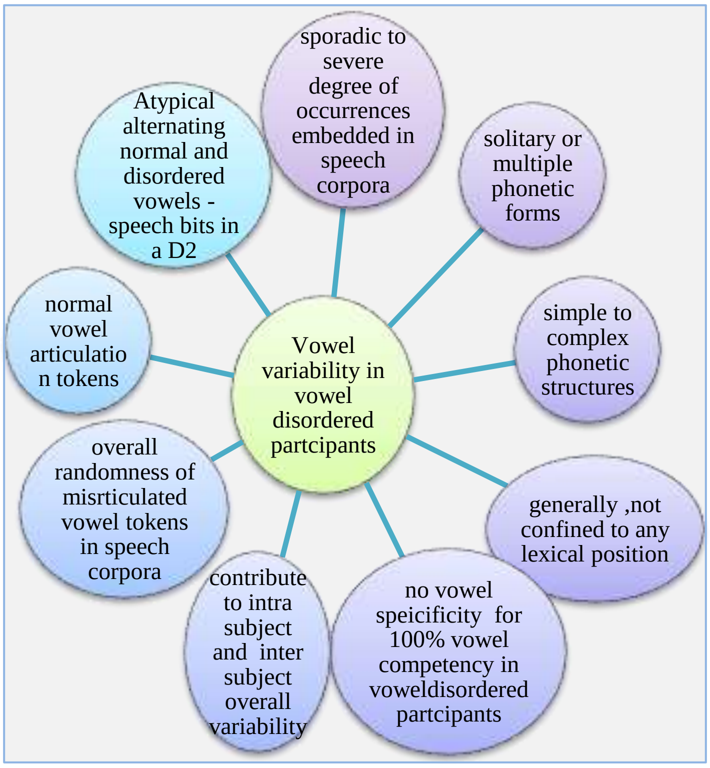

Figure 6 Characterizations of vowel variability in vowel disordered participants

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5.5. In solitary vowel variability, vowel tokens randomly jump from normal articulation of concerned vowel to only one type of misarticulated vowel. In multiple vowel error forms, a vowel randomly jumps from normal articulation to any of its misarticulated forms within its inventory .These contribute to intra subject vowel variability of a vowel in focus.

5.6. Occurrences of misarticulated vowels in lexical positions also remain as variables. They are generally not confined to any of initial, medial or final lexical positions.

5.7. It is beyond the scope of this initial- study to comment on lexical phonetic contexts and vowel variability

5.8. A unique nature of atypical vowel variability is seen in D2. (3.3).

5.9. No vowel specificity is identified for vowel variability (2).

These characterizations of vowel variability 5 to 5.9 in vowel disordered participants are illustrated in figure 6.

It can thus be inferred from numerous vowel variability tokens in the vowel- affected participants that vowel variability is universal to all participants in groups D1, D2 and D3 wherein 100% competency is not identified. No vowel specificity is identified for vowel variability. Finally, they remain embedded in speech corpora of congenital SNHL speakers in a random manner with random occurrences.

100% vowel competency or random vowel variability which comprise normal vowel articulation it's misarticulated counterparts is found embedded in communication speech corpora of congenital SNHL participants D1, D2 and D3 showing no vowel specificity for their random behaviors .These are residual vowel behaviors in D1 ,D2 and D3 after LT-CAOSLT

Discussion

The purpose of this initial study was to explore if D1, D2 and D3 show evidences of 100 % vowel articulation competency after LT-CAOSLT in the dynamics of spoken communication. Alternatively, the goal was also to identify if any specific vowel in vowel –disordered participants show 100% vowel articulation competency.

The arguments for initiative of this study on vowel competence in SNHL arose from examination of developmental reports in vowel acquisition in normal children which indicate early vowel acquisitions and findings of vowel defects in studies in hearing impaired. It is well known that vowels are acquired much early than consonants in developmental years (Banu 1977; Buhr 1980; Bassi,1983; Bond, Petrosino & Dean1982; Kumudavalli 1973; Vihman 1996; Paschall1983; Irwin & Wong 1983; Stoel-Gammon & Dunn1985; Templin1957,Ling 1976). Auxiliary findings on vowel acquisitions are also drawn from research in mental retardation. A retrospective probe was conducted into the case sheets in age group between 6-14 years enrolled in special centers in Bangalore between 2000-2007.inspite of the cognitive delays in Severe- moderate, moderate ,mild mentally retarded children, there is general absence of vowel disorders (Gayathri, 2007). Alarmingly, the notion that 'vowels *are easy to achieve developmentally'* is in dissonance in adult cognitively normal congenital SNHL population. Vowel articulation defects continue to occur even though they have undergone LT-CAOSLT for 18 years, with most of them having completed speech and language aural- oral therapy .These are attributed however to be due to degraded auditory information of speech input provided by the hearing devices to SNHL subjects. Auditory feedback is important both for learning and for monitoring articulation at speech production. It is known that unlike in consonants, the vowels lack contacts between the articulator and the place or point of articulation, which cause a major hindrance, when feedback through oro- motor kinesthetic sensory feedback is demanded at speech production. In the context of degraded auditory feed back at vowel articulation such as for example in D1.these may be contributing factors for vowel misarticulations and their variability, in spite of normal articulation tokens discovered in their speech corpora.

Current study, on conversational speech corpora provides robust natural array of phonetic contexts in uttered lexicons of target language. Studies on vowel segments within participant's own conversation inventory are lacking in congenital SNHL. In this study, the vowel phons are studied within their lexical units in their utterances at dyadic conversation task. . The dyadic conversation approach adapted in this study through the use of a section of TELS –Kannada ,engages the participant in higher order thinking for time bound responses ,verbal recall, lexical selection , formulation of grammatical structures ,self repair at speech production(Levelt, 1989; Levelt et al., 1999, Goh 2003) . These are demanding and active tasks of natural daily communication unlike passive speech sampling. It is assumed that at speech production, the speech producer goes from message to sound via each of these levels (message → semantics → syntax → phonology → sound), in the integrated theory of language production and comprehension (Pickering&Garrod2013). In this investigation, vowels show far resilient competency in such complex tasks in mainly 4 participants in D3, AhifSNHL in D1 and one Adult D2 user (figure7). On the other hand ,all other adult congenital SNHL participants in this study under D1 D2 and D3 hearing domain lacked vowel competency at conversation ,even after completion of long term speech and language therapy for as long as 7-18 years(figure 7).

The accessible residual hearing in low frequencies in adult hifSNHLD1, which is essential for auditory feedback of vowel segments, has facilitated normal vowel acquisition unlike all other D1 participants .This result is in agreement with previous studies, wherein analogue Ahifsn D0 user shows no vowel defects and thus 100% vowel articulation competencies like in D1Ahifsn participant (Gayathri 2016, 1983). A study by Stelmachowicz , Pittman, Hoover, Lewis & Moeller (2004), however indicate that even the early identified hifSNHL with hearing aid, also show shortest delay vowel segment acquisitions . If results from preliminary study in D0 (Gayathri 2016) is cumulatively included into this current study , then even Ahifsn D0 has 100% vowel artciulatory competence and ApsnD0 belongs to second group of vowel artciulatory ability with their misarticulation variability.

As a group, the D3 implantation has helped catalyze the learning of the easy to develop vowels in four out of six participants. Supporting results for early and normal vowel acquisition in D3 users are seen in studies by Adi-Bensaid & Tobin (2010), Ertmer et al. (1997), Tye-Murray & Kirk (1993); Tobey & Geer (1995); Tobey, Geers & Brenner. (1994); Serry & Blamey (1999) ; Warner-Czyz & Davis (2008); Ertmer, Young, Grohne, Johnson, Corbett & Saindon (2002) have highlighted that that increases in the diversity of vowel and diphthongs were among the first signs of benefit from cochlear implantation. They also implied that the early emergence of these sounds suggests that they were perceptually salient and relatively easy to produce given the signal from the implant. That Early D3 implantation in congenital SNHL is critical to normal developmental process of vowels is highlighted by Connor, Craig, Raudenbush, Heavner & Zwolan (2006) and Zamani, Zarandy, Borghei, Rezai & Moubedshahi (2016).

All vowels show normal vowel articulation along with randomly embedded misarticulated vowels in their large speech corpora in the participants with vowel disorder in this study. No vowel specificity is identified for 100 % vowel articulation competency in the second group. This group thus has the vowel articulation capability associated with their variability in misarticulations. The variability's in vowels are attributed to poor monitoring at articulation due to degraded auditory feedback for nearly a century. They remain as residues in speech of congenital SNHL. The natural speech corpora in this study has provided for elucidation of many tokens of inconsistency in vowel articulation. Inconsistent vowel misarticulations with a continuum of normal vowel articulation tokens were seen for all vowels show randomness in their occurrences. . They remain embedded in the speech corpora. This makes it difficult to infer that a specific vowel is not acquired in these participants. Universally, the occurrences and nature of all ten vowels are superficially similar and undifferentiated within the speech corpora. Their overall characteristics and randomness is illustrated in 5-5.9. That vowels show random variability from normal articulation to multiple misarticulations in the vowel disordered participants, in natural speech conversation contexts can however be inferred from this current study in D1, D2 and D3 in general. Vowel variability is thus the signature vowel behavior in residual vowel disordered participants in this study. They are present in large number of tokens in their speech corpora. Their nature of variability and considerably mild to large numbers of occurrences associated with normal vowel articulation tokens in speech corpora after LT-CAOSLT is a challenging phenomenon to understand. They deserve intense probe which is under taken in subsequent research under parent study and will be published in successive research papers in vowel series in near future.

This study points to the fact the early identified congenital SNHL infants fitted with D1 device, for both of whom the D2 device was not economically feasible and D3 was not available at that time, continued to show random residual vowel errors in spite of completion of LT-CAOSLT. On the other hand, four D3 users in this study identified and intervened by age 2 years had achieved 100 % vowel competency in Kannada at natural conversation after 2-4 years of speech and language therapy. With proliferation of awareness programmes, and early SNHL identification programmes, the health care bodies must also equip with skills and technicalities of efficient D3 hearing device interventions and intensive speech language therapy for successful out comes in daily communication. It can be concluded that from this that effective hearing device such as D3 reduces total therapeutic duration with efficient vowel articulation in general. There are also possible chances that D2 device over rules defective vowel articulation in Aspsn, as indicated in one spsnD2 in this study and sporadic vowel defects on another D2 user.

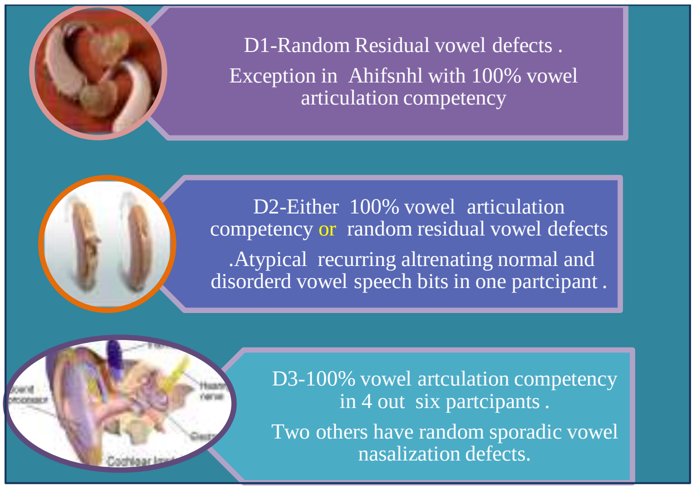

Figure 7. Comparison of vowel articulation competency in 3 different hearing domains

Conclusions

Two types of participants emerge from data analyses. One set of participants from D1, D2, D3 (figure 5) hearing domains did show 100% vowel competency post LT-CAOSLT. The second group remained vowel disordered post LT-CAOSLT. Randomly variable misarticulated vowels are seen in second set of participants with vowel disorders in all three groups. They also show the characteristic nature of associated articulatory potentials to articulate these vowels with accuracy. Characteristics of variability in speech corpus are illustrated (fig 6). Alarmingly, there was not a single vowel which showed 100 % vowel articulation competency in this second group even after LT-CAOSLT

.Embedded random variability of vowels in a continuum of normal articulation to multiple misarticulation manifestations is significant in their natural speech corpus. They manifest vowel artciulatory capabilities with variable vowel misarticulations. The considerably large number of these variable vowel tokens in conversation corpora demand further in depth probe, which will be pursued in series of vowel studies in future.

Limitations

This approach is highly time- consuming for daily clinical use but it identifies novel results at data searching of communication corpora. Another limitation is that, there is need for more number of D2 subjects under the ongoing parent study.

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A Critical Edge to Conventional and Auxiliary Vowel Error Typologies Embedded in Kannada Conversational Speech Corpora of Congenital SNHL with Contemporary Hearing Devices, II

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Abstract

Congenital Sensorineural with three different types of hearing devices were administered a conversational task from TELSHI/Kannada. All participants had completed long-term comprehensive aural-oral therapy (LT-CAOSLT) and were main- streamed to normal schools. Three hearing domains D1 -analogue behind the ear hearing aid users, D2- digitally programmable BTE hearing aid users, and D3-the cochlear implanted were compared for vowel error patterns in their conversational speech corpora . The data driven approach has revealed auxiliary vowel error typologies grounded in the data in addition to conventional SODA misarticulations. While diphthongization is reported in SNHL literature, Triphthongization of vowel is not. It is argued that even though V .V hiatus patterns are impact of medial consonant omission in word contexts, they are vitally conspicuous in SNHL conversation with their distinct phonetic structures. Combined typological errors are also prevalent in that they needed a separate and associated marker due to their multiple formations with range phonetic complexities. Comprehensive descriptors and re- groupings of vowel error typologies in speech corpus help in projecting their phonetic complexities and their collective representations help to define speech of a congenital SNHL or a SNHL group and their effective clinical comparisons.

Keywords vowel, misarticulation, SNHL, deaf, cochlear implant, analogue behind the ear hearing aid, programmable digital BTE, misarticulation, typology, conversation, SODA, phonetics

Introduction

Sensorineural hearing loss at birth (figure 1) drastically affects speech and language acquisition. This includes even the vowels segments .Literature in speech production of congenital SNHL portrays vowel misarticulations in different ways. Numbers (1936) first pointed that the substitution, neutralization, diphthongization, nasalization and prolongations are vowel misarticulation in the deaf. He had also included diphthong misarticulation with pure vowels in his study .Markides (1983) had approached the problem of vowel misarticulation in deaf and partially hearing children under the same four groups for vowels: substitution, neutralization, diphthongization, and prolongations. Osberger & Mc Garr (1982) has also reviewed vowel misarticulation under these headings. Levitt, Smith, Stromberg, & Gold (1976) identified speech sound errors that are common to and those that separate the deaf who go to sign language education versus oral education .Ling (1976).also has discussed neutralization, diphthongization and nasalization of vowels. Suppositions of Ertmer, George, & Karlan (1996) include tense-lax substitution, substitution of a neighboring vowel, vowel omission, diphthongization, unidentifiable productions, and centralization or neutralization as primary vowel errors in hearing impaired. Long vowel substitution, diphthongization, shrinkage of acoustic vowel space in hearing aid users after long therapy were found by Nicolaidis & Sfakianaki (2007). Sfakianaki & Nicolaidis (2016) have attempted studies on vowel substitution ,elongation , neutralization and diphthongization properties of vowels acoustically .Łobacz, François, & Szalkowska (2002) present that some significant phonetic processes are centralization , the considerable reduction of articulatory movements of the tongue, nasalization in oral contexts in vowels. Kato & Yoshino (1988) have also reported neutralization, diphthongization inappropriate vowel nasalization in their review. Vowel substitutions and vowel errors are extensively reviewed by Verhoeven, Hide, Maeyer & Gillis (2016) and Thirumalai, & Gayathri (1980-82, 1988, 1994) respectively .Studies in Kannada have also identified vowel nasalization, diphthongization (Gayathri 1983), and V.V hiatus, and vowel durational changes in speech corpora (Gayathri 2016).

Parker (2005) found significant vowel substitution and vowel neutralization in age range of typical speech acquisition in D3 children. That the inaccurate vowels were realized as either partially correct or incorrect was found by Warner-Cozy, Andrea &Barbara. (2008)

It can be observed from these studies that instead of using the clear-cut conventional four labels of SODA for the classification of vowel misarticulations other additional terms such as neutralization, centralization diphthongization, and nasalization and prolongations are brought forward to depict the hearing impaired speech.

The purpose of this study is to identify types of vowel errors in conversational speech corpora of three groups of congenital SNHL who encompass use of different types of rehabilitative hearing devices D1, D2 and D3 in Kannada. To organize the vowel error typologies identified in the conversational speech corpora in the context of Indian languages in these study .All participants had completed long term comprehensive aural oral speech and language therapy in Kannada (LT-CAOSLT).

Method

It was the aim of this study to capture and label all vowel error typologies in speech of congenital SNHL in D1.D2 and D3. The parent study contains 18 congenital SNHL subjects who had completed intensive long-term oral- aural speech and language therapy. Their mother tongue and regional tongue was Kannada. They also wore three different contemporary hearing devices: analogue behind the ear hearing aid, programmable digital behind the ear hearing aid and the cochlear implanted named as D1, D2, D3 hearing domains (figure 1, 2, 3, 4). Table1 in appendix in this paper provides clinical details of 18 participants in this study.

Conversation section from TELS HI /Kannada (Thirumalai & Gayathri 1982, 1988) was administered in a silent room in face-to-face context. The same was recorded with high quality Sony digital audio recorder with microphone. IPA transcription was adapted with fine attributions where needed for phonetically abnormal word units up to their utterances. Details of methods can be seen in Gayathri Vowel I, 2019. Qualitative perceptual approach was adapted to make judgments of vowel phons and transcriptions (also see Gayathri2019 vowel series 1 for additional participant details).

Figure1. Affected parts of the ear in irreversible congenital SNHL.

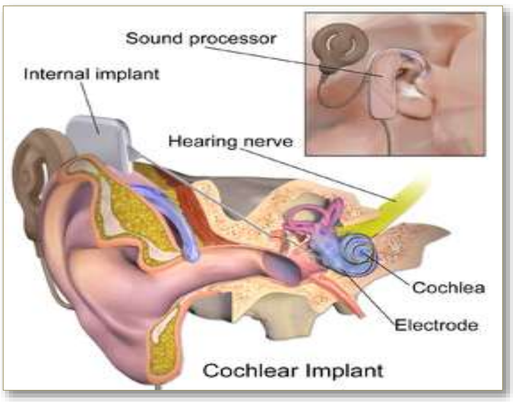


Figure 2: Domain 1, D1, analogue behind the ear hearing aids

Figure 3 Domain 2, D2, programmable digital behind the ear hearing aids.

Figure 4: Domain 3, D3, the Cochlear Implanted

A novel approach to document lexical transcription was adapted. Word by word transcription of conversational speech corpora was undertaken systematically .In each lexical transcription, flower

1. Apsn_Domain1
2. Aspsn_Domain1 n=2
3. Amssn_Domain1
4. Ahifsn_Domain1
5. Cpsn_Domain1
6. Cmssn_Domain1
7. Apsnsib2 Domain1
8. Aspsnsib2 Domain1
9. Aspsn D2 Domain- n=3
10. D3 Domain - n=6

All participants except CpsnD1 and CmssnD1 had completed speech and language therapy

D1= Analogue BTE hearing aid user, both ears, n=9

D2=Digital programmable hearing aid user. All were children, both ears

D3= Cochlear implanted (in one ear), age @sampling = 8-10 years, post speech and language developmental period

Sib2=second congenital SNHL sibling in family

C, D1= child, ongoing speech therapy , and language experience for 7 years, parallels with child D3

A=Adult

Clinical User friendly acronyms for degree and type of SNHL e.g. psn=profound SNHL, hifsn=high frequency SNHL, mssn=moderate severe SNHL

Criteria of sampling – Completion of long term aural- oral speech and language therapy, congenital bilateral symmetrical SNHL, main streaming to normal schools; Incidental Sampling

Total n=18

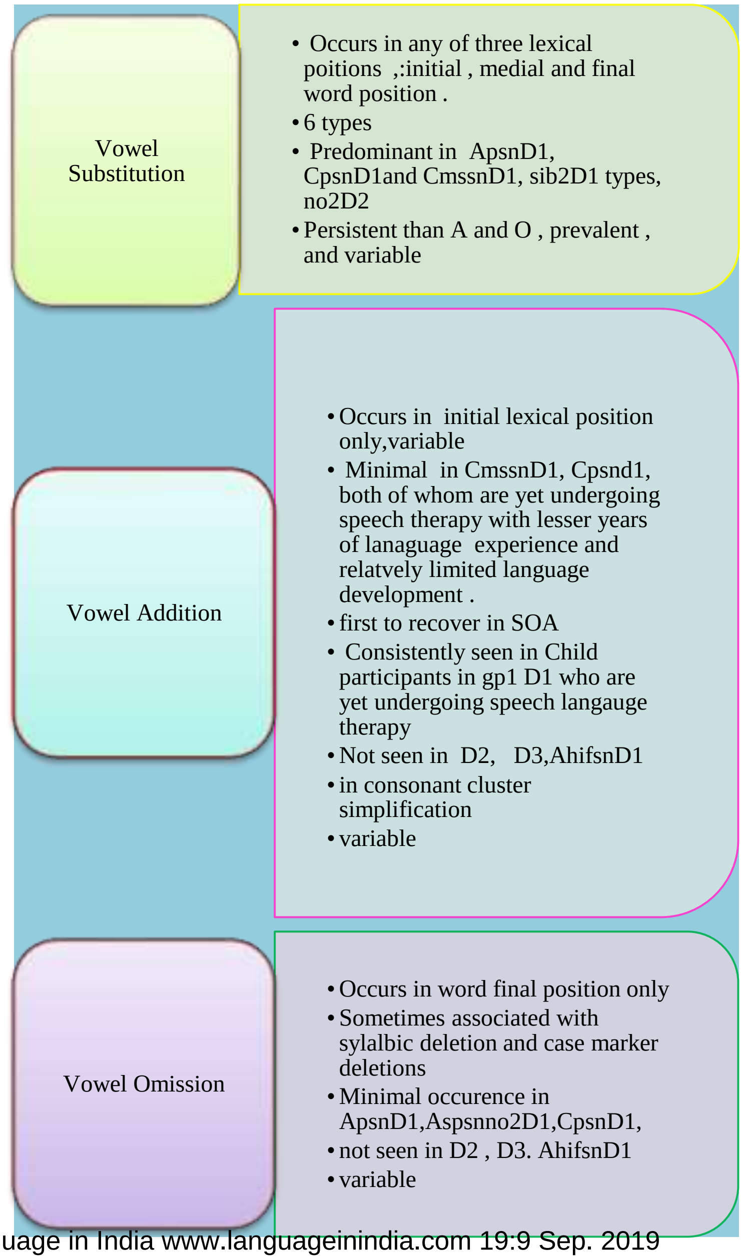
Table1. Clinical details of D1, D2, D3 participants in this study, n=18

brackets are used for subject is misarticulated phonetic segment with target phone was written adjacent to it in regular brackets. E.g. if [ADalla] is target lexicon, misarticulated phones within this target lexicon was documented as [A{d}(D)a{l}(ll)a].In [A{d}(D)a{l}(ll)a] those phones in flower brackets are defective : {d}and {ll} . Their target phones are [D] and [ll] which are by their side in regular brackets. This approach provides for reviewing the error pattern in word in their normal phonetic order. By skipping flower brackets participants target word is read, and by skipping regular brackets, misarticulated word is read. By observing, the phonetic units within square brackets judgments were done in word context. Overall, they provide for phonetic and phonotactic contexts of the subject's articulated phonetic segment and also the target phonetic segment simultaneously. Thus, the phonetics of target and participant's production can be compared in this method of new coding. This method also has multiple applications which are applied in next series of studies planned under the parent study.

Each participant's transcribed profile in word contexts was examined. Data searching was done to identify and label vowel errors. The approach in this study differs from conventional approaches in hearing impaired literature, for it aims to capture all vowel deviancies embedded in the conversation speech corpora. Similar phonetic errors were sorted and compiled separately .Triangulation and constant comparison technique of qualitative research methods were adapted to recognize the significant presence of vowel error pattern in a participant. Those vowel error patterns occurring more than 2 times were recognized as a vowel error pattern in participants' transcribed speech profiles.

In next step, each vowel error pattern for ten vowels of Kannada (Upadhyaya 1972) was sorted first under conventional SODA. Every sorted misarticulated vowel with its word unit was tabulated under headings: substitution, omission, distortion and addition.

Figure 5 SOA characteristics of vowels in D1, D2 and D3 conversation speech corpora.



Further data searching revealed remaining vowel errors patterns that did not align with SODA .Attempts were made to critically analyze their phonetic structure and establish a non-redundant sorting and labeling process for these auxiliary typologies.

Results

Results are classified under the conventional SODA misarticulated vowel types and auxiliary vowel error types.

Conventional SODA error types

While substitution, omission and addition of vowels clearly portray some proportions of the vowel misarticulation types, none of vowel errors could be tabulated under distortion errors due to their clear perceptual quality. Therefore, a distortion defect is eliminated for classification of residual vowel disorders in SNHL. Thus, SOA (figure 5) errors mainly define some proportions of residual vowel errors in congenital SNHL D1. The occurrences of vowel substitutions are most predominant than vowel addition or vowel omission defects. Each of these is discussed under respective sections below. The data driven approach also unraveled the existence of other vowel error typologies.

1.1 Vowel substitutions (Sn*).*

When a target vowel in lexicon is substituted by alternate phonetic segment then it is termed as Sn . It means that a different phonetic unit has swapped a specific target vowel unit within a target word. Following are some of the phonetic characteristics of typical vowel substitution error patterns (see figure 5and 6) in congenital SNHL. This definition also takes into consideration broader perspective of Indian languages. For example, nasalized vowels in lexicons are considered as Sns . This is because, in many Indian languages, nasalized vowels have phonemic significances . Similarly, vowel lengths are phonemic in all Indian languages and hence the durational changes of vowels deserve to be grouped under Sns. When vowels are substituted by non pure vowels, they are known as vocalic Sns for example 2 and 5 below. Following are different Sn patterns that are identified in conversation speech corpora of congenital SNHL.

1. Substitution by **alternate vowel** or **alternate vowel on vowel Sns, V-V** *p {O} (u){b}(Tb)A{lL}(l)u.*

2. Substitution by **Diphthong** called as **Diphthongization (DZn),** *d(uo<}(O)te , {t}(n)A(a)R{EEi)(i) a.*

3. Substitution by a **Consonan**t, *{A}(a){ qq }(i) Lilu* .

4. Substitution by **nasalization** of target vowels in a lexicon . *m{a~}(a)duvE*. This classification is specific with a broader perspective to Indian language contexts . In some Indian languages, nasalization of vowels is phonemic. e.g.: Punjabi.

5. Substitution by **altered vowel duration** in a lexicon which includes long -short vowel confusions. *n{a}(A)nu;k{aa”>}(a)n(l){uu”~>}(u),{c*}(c)i{tt}(tr){A>}(a)r{AA>}(A){n<}(-nn-){a-}*. Sometimes, in D1 users such as ApsnD1 are seen vowel durations as long as up to more than 5 times the target vowel unit.

6. Explicit Triphthongizations (TZn).

In Explicit Triphthongizations, the target vowel is very clearly identified without ambiguity in its word context .Hence they are called as *Explicit Triphthongizations under substitution. n{uoƆ}(O)Du* , *k{uoƆ}(O)Du*. In this example, triphthong{uoƆ} is substituted for vowel [O].This is different from Hazy Triphthongization discussed later .This defect is highly conspicuous at the listener's end and also more complex than single vowel Sn and diphthong Sn .

Except high frequency D1, every one of D1 users which include the profound, severe profound, moderate SNHL and two of three digital behind the ear hearing aid userD2, and two D3 ussers demonstrated the substitution articulation disorder. Four cochlear implanted, the D3 users and one D2 user had no substitution defects. These are illustrated in figure 8 along with coalesced vocalic Sns described later.

7. Alien vowel Sns

Another finding is that five vowels [ae] [ʌ] [Ɔ] [ɑ] and [ə] alien *to Kannada inventory* are some non Kannada vowel substitutions . [*ae*] was common amongst the three . Only the D2 user had showed common [ɑ] [ʌ] and [Ɔ] substitutions. These are grouped under vowel Sns itself, or the **alternate vowel on vowel Sns, V-V (1)**. They are identified in both D1 and D2 speakers

Substitutions errors are the predominant error type in residual vowel errors in D1 and D2 in dyadic conversation tasks post LT –CAOSLT. This finding is supported by Gulian , Hinds & Nimmo-Smith(1986) , Verhoeven, Hide, Maeyer & Gillis' (2016) review and Gold (1980). Consonant substitutions are least frequent of all substitutions. The Consonant substitutions are not reported in most other studies. Both D1 and D2 speakers showed consonant substitutions for vowels. With the exclusion of this type of substitutions remained the '**vocalic vowel substitutions'** e.g. [ae] for [a], [ou] for [u], [eia] for [i] in D1. Vocalic Sns not only include pure vowels Sns but Sns such as by diphthongizations and explicit triphthongizations. **Similar vowel substitutions** are the only type of substitution pattern in an AspsnD1 speaker who is relatively a fluent speaker at dyadic conversation .These vowel substitutions are similar to target vowel phonetically with differences in either only duration and nasalization variations with respect to target vowels (e.g. [A] for [a] or [a~] for [a], or both . Other vowel Sns are grouped under **dissimilar Sn types**. They comprise the alternate V-V Sn , TZn , and DZns. These will be dealt with in successive research paper on vowels .An alternate dissimilar vocalic substitutions with different phonetic vowel structure comprised alternate vowel on vowel substitutions. V-V, diphthongization substitutions and triphthongization substitutions. Sometimes these are further complicated with coalesced durational variations or nasalization or both. They contributed to increased complexity of substitution defects e.g. ; they are named as; **coalesced vowel substitution defects** e.g. *m{E~}(a)nn{e~}(e),m{A~>}(a){-du}w{ei~<}(e), {t<d}(d){u<O~>}(O){n}(N){i~}(i),k{aa">}(a)n(l){uu"~>}(u).* These types are seen in both D1 and D2 speakers. All these types of vowel substitution defects can be seen depicted in figure 5 and 6. Diphthongization and Triphthongization substitutions are absent in D2 and D3 speakers and AhifSNHL speaker .But they are present in other D1 speakers.

It is thus important to enhance the terminology of Sns with its sub types. They comprise a range of phonetic types and complexities which deserve a separate mention as above for clinical assessment and therapy .

1.2 Vowel addition.

In this error pattern, an additional vowel segment makes appearance *{A+}{pp}(p)U{r>}(r)I* in the target word. Vowel additions are seen in child SNHL D1 participants who had limited experience in language therapy compared to adult population who had completed speech and language therapy in this study (table 3, figure 5). They are seen in word initial position unlike Vowel omissions is seen in word final position. . Vowel Addition defects are absent in D3, D2 they a*lso show* Coalesced Complexities with added durational and nasalization phonetic parameters.

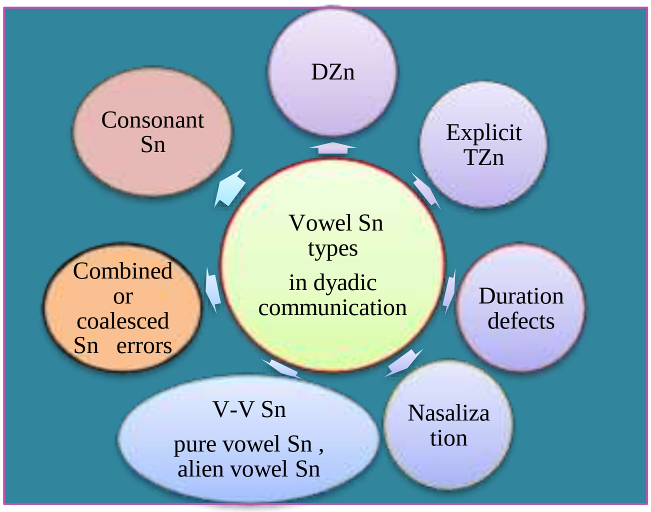


Figure 6: Patterns of vowel substitution (Sn) in conversation in congenital SNHL in Kannada.

Vowel additions are also seen at simplification of consonant clusters, either by themselves or with Coalesced Complexities, hence causing noticeable attention in the listener at dyadic conversation.

1.2 Vowel omission

When a vowel in target lexicon is omitted then it is termed as vowel omission .It occurs in word final position only in residual vowel errors in congenital SNHL . Sometimes it is associated with syllabic deletion and case marker and syntactic deletions(figure 5) *Am(Ele-), pe{c}(ns){EE}(i)((llu-, A{w}(m)El((e-; ta{k}(rk)Ar(i-)*. They show rare occurrences in Amssn D1 and Aspsn D1partcipants compared to adult profound SNHL D1 type and child D1 who were still undergoing speech and language therapy.. Warner-Czyz, Andrea &Barbara (2008*) have* also found that Vowel Omissions occurred less frequently in their subjects.

1.4 Vowel distortions .None of residual vowel errors are found under distortion in the participants of current study.

The above paragraphs 1 to 1.4 illustrate conventional SOA vowel error These are depicted in figure 5. Non SOA vowel error patterns that remained in the speech corpora after SOA classification are discussed under 2 below.

2. Auxiliary vowel error typologies .This includes vowel articulation errors which cause undue attention in the listener, but which do but fall under the conventional SODA classifications. These are Hazy Triphthongization and atypical V.V hiatus. They are exclusive and non redundant with SODA vowel error typologies.

2.1. Hazy or Fuzzy Triphthongization. Triphthong formations are strikingly conspicuous calling attention to the listener. This Triphthong is absent not only in Kannada language but also absent in most other Indian languages that are documented by Ramaswami (1999).

Instead of single vocalic phonetic structure, there appear three non interrupted and glided vocalic component phonetic segments in their uttered word. In hazy -Triphthongization unlike the explicit- Triphthongizations the target vowels cannot be traced from word.*{eii~A}(?)wati,–bAie<y(-gg?)E, b{Eie<}(-L?)yE* . They also show Coalesced Complex Tiphthongization error pattern. Some Fuzzy *Triphthongization* tokens are six times longer in duration relative to single short vowel segment duration with super imposed nasalization and hence are highly conspicuous.

A significant observation is that those participants who presented Triphthongization also had diphthongization in their speech corpus, but not the converse rule .They are seen in Aspsnsib2 D1, child mssnD1 and AspsnD1 no2 . They are absent in D2 and D3 users .They too go through combined errors nasalization and prolongation of either one element or all. AspsnD1 no2 showed only pure Tiphthongization .These makes them even more noticeable in their speech production.

Fuzzy Triphthongizations are absent in D2 speakers .They are common in child severe profound SNHL who had undergone 7 years of speech and language therapy and a sib2D1 speakers with relatively limited language achievements. However, she had completed LT-CAOSLT for 17 years

2.2. V.V hiatus occur due to medial consonant deletion within a word unit. This means that two adjacent vowels are incised by silent gap : *Od{a.a }(-ll), t{A.i}(-ng) b{a.u<}(-r)t(e-) k{a<.e}(-g)* .But, sometimes silent hiatuses are intervened or incised with audible glottal stops preceding and following audible silent hiatuses *[{a.ʔ.u}(T-)Du]*. The vowels which are adjacent to hiatuses are also coalesced with additional prolongation and nasalization, of either first or second vowel element or both in their permutation and combinations. An example of *V.V* .Coalesced Complex *is : mai{t}(s)U{r*}(r){A.a~}(-r)m{a~}(a){nn}(n)e*. It is possible that the hiatuses are expressions of blocked vowel stream ,or the impact of intentional glottal stop insertions or substitutions at hiatuses .

Because of their audible conspicuousness in conversations and their presence in multiple phonetic complexities, they are grouped as one of error typologies in this study. V.V hiatus are absent in D2 and D3 speakers and AhifsnhlD1. In AspsnD1 and AmssnD1 are observed that silent hiatuses are overcome at medial consonant deletion, but adjacent syllables amalgamate fluently in vowel stream which cannot be also labeled as diphthongization. It is emphasized that V.V hiatus is not a vowel misarticulation defect by itself, but it is a definite pat of vowel corpus in natural conversations of congenital SNHL, which is has a undue conspicuous negative impact in listener at dyadic conversations. It can be seen in figure 8 that it typifies in residual vowel error cluster of D1

3. Combined error occurences The combined or coalesced errors with vocalic phonetic complexities can be found associated with vocalic substitutions, vowel Sns, vowel additions, and V.V

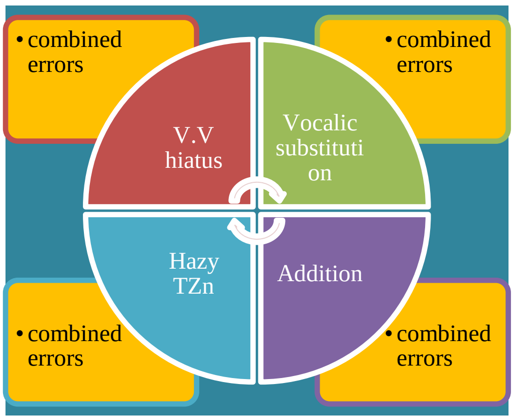


Figure 7 Combined Error Occurences

hiatus and hazy Triphthongizations (see Figure7).

4. Variability of vowel errors is seen in D1, D2 and D3. Some vowels show all three vowel error patterns of SOA, substitution, omission, addition and normal vowel articulation within the same participant. Intra subject variability is also reported by Ling (1976), Osberger and Mc Garr (1980), Sfakianski & Nicolaidis (2016) in hearing aid users. Verhoeven,Hide,Maeyer,Gillis & Gillis(2016) also emphasized that main difference between the D3 and NH group pertained to the intra-subject variability in formant values which is significantly higher in CI children. Their characterizations can be seen in previous paper , Gayathri 2019a ,Vowel Series- 1 . It is highlighted here that all vowel error typologies presented in the current study are variable, spread out in the conversational corpora .

5. Multiple occurrences of vowel errors in same word. *This data driven study of speech corpora also brings to light multiple occurrences of vowel error patterns in same word unit*: *{aa~>}(a)m(mm){AA~>}(a), n{EE}(a)R{ei<}(i).* These further get complicated with additional consonantal segmental errors in the same word units, particularly in D1 speakers *w{u<O">}(O){n}(N)i, {t<d}(d){u<O}(O){n}(N)i* for same word [dONi] seen in ApsnD1 for example. They cause drastic corruption in word intelligibility in conversation. Variability of these in addition aggravates the decoding difficulty in listener at dyadic conversation, which may be helped in some cases with contextual cues and familiarity with the speaker. These *Multiple occurrences of vowel errors in same word types* are seen commonly in ApsnD1 .They are reduced in AspsnD1 congenital SNHL types. However, they are not seen in AmssD1 and D2 speakers.

6. Further, the **recurrence of same lexicon** in speech corpora does not ensure that the vowels are in phonetic resemblance in two occurrences. E.g.: *(n-)) {I~}(i)ru, n{I>}(i)rU* for target word *nIru* .

7. Comparison of residual vowel error typologies between three different types of hearing domains D1, D2 and D3.

These are listed in following lines below (figure 5).

7.1. Neither SOA nor auxiliary error typologies are found in four of six cochlear implanted, one of three D2 speakers and AhifsnD1.

7.2. Vowel additions and omissions of SOA type, hazy triphthongizations and V.V hiatuses of auxiliary error types are seen only in D1 speakers.

7.3. Substitutions are predominant in D1 and in one D2 speaker. They are the only type of vowel defects in two D2 speakers and two D3 speakers.

7.4. Variability of errors from normal to defective occurrences are seen in D1,D2 and D3 groups

7.5. Multiple occurrences of vowel defects in same word are seen more commonly in CmsD1, CspsnD1, sib2D1, ApsnD1 and ApsnD1. Exceptions to this group in D1 are AmssnD1 and an

AspsnD1. The affected D2 speaker also presented multiple occurrences of vowel defects in same word..

7.6. Coalesced errors are seen in both vowel- disordered D1 and D2 users.

7.7. Hazy triphthongizations are absent in ApsnD1 AspsnD1AmssnD1. However, they are present in both child D1 speakers who were undergoing speech and language therapy and in psnsib2D1 speaker. All these participants typically had relatively limited language use compared to the rest of the participants in this study.

7.8. Vowel additions, vowel omissions, hazy triphthongizations and V.V Hiatuses distinguish between D2 , D3 versus the D1 speakers. All these defects are present only in vowel affected D1 speakers in current study

7.9. Vowel disordered D2 speakers are better than vowel disordered D1 speakers. The Sns in D2 are matched for number of elements in phonetic segments. Only monophthongs are substituted for monophthongs in D2 speaker's .But D1 speakers presented diphthong and triphthong Sns occur for monophthongs, termed as vocalic Sns

. Further, excessively long duration of affected vowels are seen in D1 speakers only. As stated earlier the highly conspicuous V.V hiatus and hazy triphthongizations are seen in D1 speakers only. Both types of speakers presented similar and alternate vowel Sn, Consonant substitution for vowels. Vowel omissions and vowel addition errors are totally absent in D2 speaker. Associated coalesced errors are seen in both types of speakers. Thus, number of types of vowel error typologies are drastically limited in occurrences in D2 speakers than in D1 speaker. However, at the same time one D2 speakers is completely normal in vowel articulation, like the AhifsnD1 speaker.

7.10. Cochlear implanted group (D3) as a whole are superior than D2 and D1 as a group , in their conversational speech with complete absence of vowel error patterns (see Figure 5) in four participants . Two other participants have nasalized vowel Sns.

7.11. Vowel error patterns noted in D1 speakers in current study are similarly represented in corresponding D0 adult profound congenital SNHL analogue body level hearing aid user found in preliminary study (Gayathri 2016) in similar conversational task and methodology..

7.12. Similarly, Ahifsn in both D1 and D0 domain had no vowel errors at all in their conversation.

7.13. Vowel variability of all affected vowels from normal articulation to defective vowels are seen embedded in the conversational speech data bases of affected speakers in both D1,D2 and D3 group .

7.14. Consonant substitutions are seen only in D1 and D2 speakers. In both groups they are sporadic residual errors .They are absent in D3 speakers

7.15 Alien V Sns are typical of D1 speakers only.

Discussion

In preliminary research, it is found that residual vowel errors persist in conversation of D1, D2 and D3 groups of congenital SNHL even after LT-CAOSLT in Kannada (vowels I, Gayathri 2019a, Gayathri 2019b, Gayathri 2016). The focus in this paper is identification, sorting and labeling of abnormal vowel error patterns in conversational speech corpora of congenital SNHL in D1, D2 and D3. Tasks for speech sampling involved dyadic conversations with congenital SNHL who had completed LT-CAOSLT. As a primary step in the current study, these were identified and sorted under SODA. This means the conventional classification comprises the substitution, omission, distortion and addition types. This approach is first followed in this study. Vowel errors at speech production comprise vowels with phonetically different structures from target vowel in lexical contexts. Data searching revealed other vowel error types, which calls undue attention in the listeners. They thus demanded separate labels. These are termed as auxiliary error typologies in this paper. The conventional and auxiliary error typologies are compared among the participants who use three different types of hearing devices in current practice in India, the analogue behind the ear hearing aid users (D1), digital behind the ear hearing aid (D2) users and the cochlear implanted (D3).

From this study on conversational speech corpora of D1, D2 and D3 speakers , additional auxiliary vowel error typologies other than SOA emerged from data searching and analyses. All these are vowel misarticulations or deviant vowel error types embedded in the speech corpora. They are non-redundant and have no overlaps with conventional SODA. They are provided with descriptive label at this juncture. They have the potential to make differentiation amongst SNHL subjects (see figure 8) through clustering of vowel error typologies. Overall findings from analyses, is that SODA does not suffice to describe hearing impaired defective vowel error patterns .Hence emerges the need for additional descriptive labels pooled under auxiliary error typologies.

In this paper the term, ***vowel error*** is used to indicate deviant vowels in the speech corpora that have emerged from this data driven research in conversation corpora. The hazy Tiphthongization and V.V hiatus cannot be attributed to any specific target vowel in target word unit. Nevertheless, these deviant vowel patterns occur within word units calling excessive undue attention in the listener. Even though, V.V hiatus are subsequent to medial consonant omission ,these medial hiatus are conspicuous due to their either silent hiatus or glottal stop hiatus , Further, either first vowel or second vowel in V.V or both might carry overlaid nasalization or durational or both deviancies . Hence, they are variable and complex phonetic structures of considerable duration that need removal in speech of congenital SNHL speakers. For these reasons the terms **vowel error** or d**efective vowel typological patterns** are generally used in this paper instead of **misarticulation** .Both these auxiliary vowel error typologies are also distinct in terms of phonetic complexity .Hence, they deserve unswerving attention of speech language pathologist at diagnoses and therapy.

Further, it is evident that substitution is broad term in current study, which is predominant misarticulation type in SNHL. Overall, the conventional broad term substitution does not demarcate the degree of SNHL speech disorder. The reasons are at least four. Firstly, it does not differentiate between single phonetic structure replacement, and a complex structure replacement .e.g.: the Diphthongization of vowels as vowel substitution versus Tiphthongization of vowels as vowel substitution. Secondly, it does not differentiate between gross disorders in phonetic selection for word formation: e.g.: vowel on vowel (V-V) substitution versus the consonant Substitution for vowels. Thirdly, it does not differentiate between Sd phonetic structures that are affected by a single vowel disorder type or those with phonetic complexities, such as a/e versus a~/e, e~/e, o/e, aie~>/e. combined errors are more severe than simple vowel errors. Last argument in this direction is that it does not differentiate between phonetic selection within target inventory or the alien vowels. All these are bound to have impacts in clinical assessments and therapeutic planning. For these reasons, it is felt that the substitution misarticulation needs a thorough probe in the speech corpora of SNHL in future with their characteristic representative demarcations as illustrated in this paper.(see figure 2) Triphthongizaton (TZn) of vowels is not reported in the literature of congenital SNHL.

Two types of Triphthongizations are identified and described in this current paper. These are Explicit and Hazy Triphthongizations. Both of which can be again superseded with duration or nasalization of vowel elements or both. None of these is reported in literature of hearing impaired speech. Presence of three distinct vowel elements holds them conspicuous in conversation. Added phonetic coalesced complexities in their phonetic structure make the situation even more complicated for listener. They are found only in D1 speakers. They are absent in D2 and D3 speakers. Some vowel errors like additions and omissions repair completely in D1.For example they disappear in some ApsnD1 and AmssnD1, two D2 and D3. Moreover, what remains as residual vowel errors in them are the bulk of vowel or vowel or vocalic substitutions in random occurrences in their conversational corpora along with normal vowel articulations.

In this paper, it is pointed that that the trends to use non SODA terms in phonetic description of vowel errors like the Diphthongization , Nasalization , prolongation were there since the beginnings of research in the deaf or hearing impaired speech production . What is highlighted here is the need for additional vowel defects types as descriptors to speech of congenital SNHLs and their ideal re -groupings and classifications. They help in clustering of vowel typological disorders to differentiate participants within the group and in between the group. These vowel descriptors in current study are based on dimensions of phonetic structures defined in this paper and phonetic complexities of vowel error typologies. .It is nevertheless concluded that SODA is not sufficed to define residual vowel error disorders in congenital SNHL speakers. All these inferences are based on post long term speech and language therapy in the three groups D1, D2 and D3 in Kannada language.

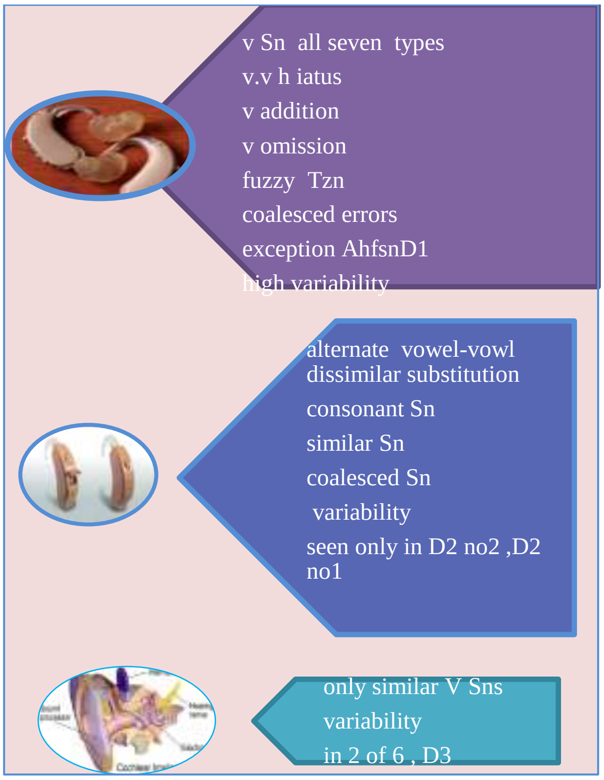


Figure 8 Comparison of vowel error typologies in three hearing domains post long term aural oral speech and language therapy illustrated.

Group1 in general shows 6 types of Sns, vowel additions and vowel omissions (see figure 8). D2 has only some Sn patterns of both dissimilar and similar types. D3 has only similar Sn patters .It s evident that clusters of the vowel error typologies differentiate between D1, D2 and D3.It is evident how these descriptors to vowel errors help in comparing D1, D2 and D3 . D3 for example has only variable similar Sns and D1 has large number of vowel error typologies. D2 on the other hand has limited types of Sns compared to D1. Vowel error variability is common to all groups D1, D2 and D3.

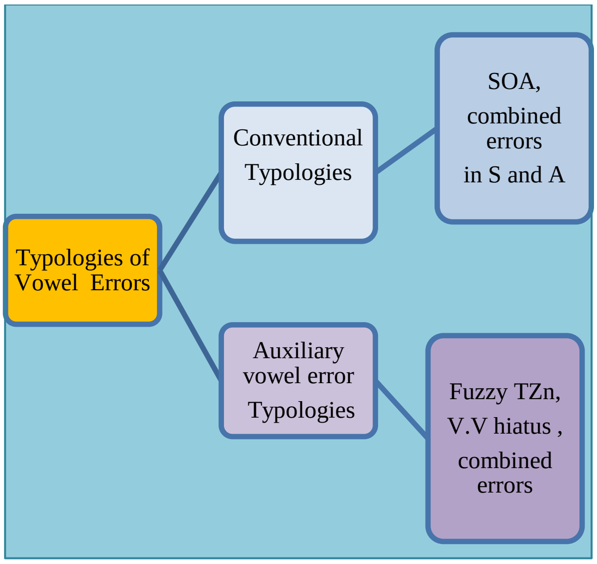


Figure 9.Conventional and auxiliary vowel error classification

The vowel error typologies identified in the speech corpora of current study, can be hierarchically arranged as shown in figure 9. They comprise mainly of conventional SOA types and auxiliary vowel error typologies which at this point suffice as descriptors to vowel error patterns in congenital SNHL speech. Coalesced errors occur in under both types of error typologies except in omission .addition of parameter of vowel coalesces indicate the phonetic complexity of vowel error typologies and their severities which has implications in clinical assessments and therapy. Clustering of the vowel error typologies facilitate in deriving vowel phonetic profiles for a congenital SNHL or for a group and their subsequent comparisons.

Conclusion

Additional or auxiliary vowel error typologies are defined based on evidence from conversation corpus in this study. They with SOA errors cluster, define, and compare the vowel error patterns between D1, D2 and D3 and within the groups. This classification has its hierarchy and scope for the representations of vowel phonetic complexities in vowel error typologies .This classification incorporates in a comprehensive manner, the terminologies reported for vowel errors in speech of the hearing impaired literature and SOA with evidences from current study . It also includes the additional findings of vowel error typologies, such as for example TZns, as descriptors to vowel error patterns embedded in the realistic conversation corpora.

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3

A Probe into 'Randomness of Residual Vowel Errors' in Kannada Conversational Speech Corpora of Congenital SNHL with Contemporary Hearing Devices: Beginning Regularities, III

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Abstract

This study aims to explore organized distribution patterns of random residual vowel error typologies under target vowel articulatory classification in congenital SNHL speakers. They had undergone long-term comprehensive oral aural speech and language therapy (LT-CAOSLT). Random residual vowel errors typologies are extracted from realistic conversation contexts and they are plotted under varied articulatory phonetic dimensions of Kannada phonetic inventory for a gestalt perspective. There exist both universal(UD) and restricted distributions (RD) of variable vowel error typologies in articulatory dimensions of Kannada vowel inventory. Four types of vowel phonetic inventory with residual vowel distribution are identified These results emerging from embedded vowel random variability in conversation are also compared across three different contemporary hearing device users: the analogue BTE hearing aids users (D1), programmable digital BTE hearing aids users (D2), and the cochlear implanted (D3). UDs of nasalization persist in vowel disordered D2 and D3 speakers. D1 shows both RDs and UDS with exceptions. This approach also sets apart an atypical D2 speaker with recurring RDS and UDS.

Keywords vowels, congenital SNHL, deaf , analogue behind the ear level hearing aid, programmable digital BTE, cochlear implant, articulatory phonetics, conversation, corpora , Microsoft search , analogue body level hearing aid ,articulation ,.phonetic inventory , residual errors, misarticulation

Introduction

Irreversible congenital Sensorineural hearing loss (SNHL) results in drastic hindrances to normal speech acquisitions including vowels . Some trends for vowel articulation in congenital SNHL are found in the literature of congenital SNHL. In 1980, Geffner had proposed that [u] and [i] are stable vowels in terms of organic formations. It was inferred that these stable vowels were more accurately articulated in analogue body level hearing aid speakers (D0). Nevertheless, a debate exists in literature as to whether front vowels or back vowels, or if the high or low vowels are affected. Specifically, such issues are discussed in D0 types that have provided relatively degraded speech input. That back vowels are articulated much better than front vowels in D1 is reported by Nober (1967), Smith (1975), Mangan (1961), and Geffner (1980). Some researchers identified that front vowels were found more often than back vowels (Carr 1953; West & Weber 1973) in D1.

Controversial results also exist on dimension of tongue height at vowel production (Thirumalai and Gayathri 1980-82, 1988, Gayathri 2019b). Angelocci, Kopp &Holbrook (1964) found that high vowels are better than low vowels in their adolescent deaf subjects of D0 types. However, Pratt & Tye-Murray (2008) report contrary results in D2. On the other hand, Geffner (1980) has reported that low vowels were commonly well articulated in D0. Nober (1967) and Smith (1975) also concluded that rest of the two tongue height dimensions in D0 is more poorly articulated than low vowels. These differences were attributed to the nature of visibility of vowels and acoustic access of vowels.

Current study explores to identify if there are distribution trends of random vowel error typologies across comprehensive articulatory dimensions of target vowels in Kannada. In the process, some underlying organization of vowel error typologies which surface randomly in the conversation corpora are hypothesized on the bases of Chaos Theory (notes1). The purpose of this paper is also to compare these regularities across contemporary different hearing device users, which includes the analogue behind the ear hearing aid (D1), programmable digital behind the ear hearing aid (D2) users and the cochlear implanted (D3) in natural conversational task. All of them had completed intensive long-term comprehensive aural oral speech and language therapy (LT-CAOSLT) in Kannada. This is first exploratory study to identify regularities in numerous random tokens of misarticulated vowels which present variability throughout the speech corpora.

It is obvious from reviews of studies above that no particular attention is laid on analyses of feature of roundedness vowels at vowel misarticualtions. The primary focus is on parameters of tongue height and visibility of vowels in terms of lingual *frontness* and *backness* of vowels. Thus, fragmented outlooks on articulatory dimensions are connected with vowel misarticulation in the literature .Phonetic Structural aspects of vowels also differ from language to language. We have no specific studies in the speech of congenital SN hearing impaired with *Gestalt perspective to articulatory dimensions*. Most of the studies have also not provided for large data sampling in the context of typical vowel variability pattern in congenital SNHL speech. In previous study, was conducted data -searching in conversational speech corpora of congenital SNHL to identify vowel typological errors (Gayathri 2019c, vowel series II).

SOA and auxiliary vowel error typologies in conversation data bases were extracted described and classified. Along with these were also noted vowel misarticulation variability ranging from normal articulation of all vowels to defectively articulated vowels embedded randomly in speech corpora data bases. That vowel misarticulation variability is the signature of congenital SNHL speech was highlighted in vowel series I (Gayathri 2019a).The problem of vowel variability in natural speech conversation data shows serious randomness with availability of multiple vowel tokens in these speech corpora. Hence, an exploratory study to identify underlying regularities in the comprehensive articulatory classification is undertaken.

Phonetic inventory of Kannada differs from that of phonetic inventory of English. Hence, language specific studies are inevitable. In this study, an attempt is made to characterize the distribution of variable vowel defects under comprehensive phonetic articulatory classification of Kannada phons. No such studies are found in Kannada. It is interesting to examine how these vowel error typologies spread across this articulatory classification of target vowels in Kannada. In this study, Randomness and multiple tokens of vowel misarticulations which are spread and embedded in the conversational speech corpora of congenital SNHL are qualitatively explored for *Gestalt perspective to articulatory dimensions in* Kannada. Vowel error typologies were inspected to *binarily* state their presence or absence in these articulatory dimensions. Kannada phonetic inventory (Upadhaya, 1972) classifies vowels in three degrees of tongue height, three degrees of tongue frontless and two dimensions of lip roundedness. By conducting this exploration, it is hypothesized patterns of distributions of vowel errors mat emerge from the data in these three dimensions. It is expected that they provide initial answers to organizations of vowel misarticulation variability and randomness in the in the virtually natural representation of conversation corpora of the congenital SNHL. Whether a particular a specific articulatory dimension be prone to any particular type of misarticulation or vowel error typology is also investigated in current investigation. The three groups D1, d2 and D3 are compared in the results.

Methods

The parent study contains 18 congenital subjects who had completed intensive long-term oral- aural speech and language therapy/their mother tongue and regional tongue was Kannada. .They also wore three different contemporary hearing devices: analogue behind the ear level hearing aid, programmable digital behind the ear hearing aid and the cochlear implanted named as D1, D2, D3 hearing domains. Figure1 depicts the part affected in the ears of congenital SNHL .figure 2, 3, 4 illustrates different hearing devices D1, D2 , and D3 Table1 in appendix provides clinical details of 18 participants in this study.

Figure 1. Affected Parts of Ear in Irreversible Congenital SNHL.

Figure 2: Domain 1, D1, Analogue behind the Ear Hearing Aids

Figure 3: Domain 2, D2 Programmable Digital, behind the Ear Hearing Aids

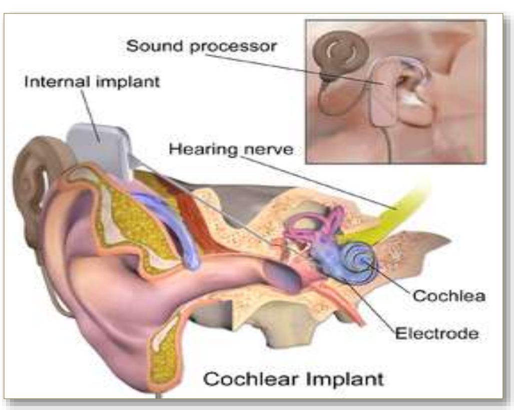

Figure 4: Domain 3, D3, the Cochlear Implanted

Conversation section from TELS HI /Kannada (Thirumalai & Gayathri 1982, 1988) was administered in a silent room in face-to-face context. The same was recorded with high quality Sony digital audio recorder with high quality microphone. IPA transcription was adapted with fine attributions where needed for phonetically abnormal word units up to their utterances.

Further details of methodology can be seen in Gayathri Vowel I, 2019a). Qualitative perceptual approach was adapted to make judgments of vowel phons and transcriptions.

A novel approach to document lexical phonetic transcription was adapted word by word

1. Apsn_Domain1
2. Aspsn_Domain1 n=2
3. Amssn_Domain1
4. Ahifsn_Domain1
5. Cpsn_Domain1
6. Cmssn_Domain1
7. Apsnsib2 Domain1
8. Aspsnsib2 Domain1
9. Aspsn D2 Domain- n=3
10. D3 Domain - n=6

All participants except CpsnD1 and CmssnD1 had completed speech and language therapy

D1= Analogue BTE hearing aid user, both ears, n=9

D2=Digital programmable hearing aid user. All were children, both ears

D3= Cochlear implanted (in one ear), age @sampling = 8-10 years, post speech and language developmental period

Sib2=second congenital SNHL sibling in family

C, D1= child, ongoing speech therapy, and language experience for 7 years, parallels with child D3 .

A=Adult

Clinical User friendly acronyms for degree and type of SNHL e.g. psn=profound SNHL, hifsn=high frequency SNHL, mssn=moderate severe SNHL

Criteria of sampling – Completion of long term aural- oral speech and language therapy, congenital bilateral symmetrical SNHL, main streaming to normal schools; Incidental Sampling

Total n=18

Table1. Clinical details of D1, D2, D3 participants in this study, n=18

Transcription was undertaken systematically .In each lexical transcription, flower brackets are used for subject's phonetic segment misarticulation with target phone written in regular brackets adjacent to it. E.g. if [ADalla] is target lexicon, misarticulated phones within this target lexicon was documented as [A{d}(D)a{l}(ll)a].In [A{d}(D)a{l}(ll)a] those phones in flower brackets are defective : {d}and {ll} . Their target phones are [D] and [ll] are by their side in regular brackets. Overall, they provide for phonetic and phonotactic contexts of the subject's articulated phonetic segment and also the target phonetic segment simultaneously. By skipping flower brackets participants target word is read, and by skipping regular brackets, misarticulated word is read. By observing, the units within square brackets judgments were done in word context. Thus, the phonetics of target and participant's phon production can be compared in this method of new coding providing space for uttered word contexts

In article on vowel series II (Gayathri 2019c), several vowel error typologies were identified in conversational speech of congenital SNHL. These include , substitution types ,omission ,addition ,hazy Triphthongization ,and V.V hiatus .For the latter two no direct inferences can be made regarding the target vowel or to a single target vowel, as in e.g. *yieiru*, *nI~>.u(-n)')*. .Hence, these were excluded in this study, as this study aims to allocate the error typologies under target vowel classification. Combined or coalesced errors associated with substitution, omission and addition, were also included in this study. Pure vowel on vowel substitutions, diphthongizations, explicit Triphthongizations, vowel duration substitution, nasalized vowel substitution, consonant substitutions and coalesced substitutions were identified in previous study. While all vocalic substitution errors were retained, the consonant substitutions were eliminated, as they obviously do not obviously fit into the vowel segments. Prototypes of error typologies are depicted in table 2.

1. Data selection demarcations of speech corpus. For this study, it was important that the vowel error typologies bear target reference vowel in Kannada in order to map them in schema of Kannada phonetic inventory (fig 5). E.g. : in*{t}(k)Ap{e}(i)* , Sn {e} has reference to target vowel (i).Similarly in *k{uo}(o)DbEkA{r}(dr)e,* DZn Sn {uo} has reference to target vowel (o). Thus, those vowel error typologies without reference to target vowel were excluded .These comprised the vowel additions, hazy triphthongizations V.V hiatus which do not bear reference of target vowel of D1.

2. The constraint of sporadic error eliminated Sporadic vowel errors with incidence of <5, In a participant's speech corpus are held as not significant. These excluded as sporadic errors in a participant.eg consonant substitutions for vowels in D1and D2.These were struck through in the transcribed data format.

3. Significant occurrences of >5 instances of vowel error typologies retained Those vowel errors with incidence of >5 in the corpus were retained which contained alternate vowel dissimilar substitution , similar substitution , diphthongization Sn, alien vowel Sns , Explicit triphthongization substitution, omission which have references to target vowels in Kannada phonetic inventory. The similar vowel Sns contained nasalization and durational Sns.

4. Re grouping of 5 vowel sets of Kannada vowels Short and long vowels in phonetic inventory were considered as one set for this analyses. Hence, there are formed 5 sets of vowels in Kannada (Figure5) which has total of 10 vowels in its phonetic inventory.

	Pattern of Vowel Error	Prototype in lexical contexts	Complex phonetic structure -Coalesced+/-
	Substitution (Sn)	{t}(k)Ap{e}(i)	
1.1	Similar Sn ,duration affected	n{a}(A)nE {t}(n){A}(a)R{EE}(i)	m{A~>}(a){w}(dw){ei~<}(e)
1.2	Similar Sn, nasalization affected	y{e~}(e){T}(NT)Uw{a~}(a)re {ky}(k){aeae~}(a)m(a~)(a)lA	m{A~>}(a){w}(dw){ei~<}(e)
1..3	Alternate vowel Sn, V-V	{t}(k)Ap{e}(i) w{o}(u){pp<}(pp){A}(i){TT<}(TT)u k{u<o }(O){D}(L){e}(i)	m{aeae~}(E)lE w{o}(u){pp<}(pp){A}(i){TT<}(TT)u {t}(n){A}(a)R{EE}(i) {ky}(k){aeae~}(a)m(a~)(a)lA
1.4	Diphthong Sn (DZn)	k{uo}(o)DbEkA{r}(dr)e k{u<o }(O){D}(L){e}(i) w{u<o}(U)Ta	b{aeae}(e)nk{i~e<}(i) n{EE}(a)R{ei<}(i) g{u<O>}(o)tti{L<ll}(ll)A m{A~>}(a){w}(dw){ei~<}(e)
1..5	Explicit Triphthong Sn (TZn)	k{uoƆ}(u)Lit((u-)	m{u>~o>~Ɔ<~}(U)ru
1.6.	Alien Vowel Sn	hi{d}(nd){ae}(i)	T{aeae~}(E)bballu
1.6	Consonant Sn	{qq}(E)ke	-
2	Addition	{A+}ppUri	{A>~+}ppUrI
3	Omission	k{uoƆ}(u)Lit((u-)	-
4	Hazy triphthongization	Aie ye	I~A~e~upu~
5	V.V hiatus	{t}(n){A.I}(a)(-r)')((i	r{A.u~}(-jk)')(u)mAr pA~.i(-r)')wA{l}(L)a

Table 2. Illustration of prototypes of vowel error typologies (Gayathri II 2019c). Those vowel error types marked in orange are considered for this study

5. Data searching and documentation phase. This method adopted for corpora study, is illustrated in following paragraph with examples and figures.

5.1. Microsoft search process for vowels- search in transcribed data If for example [a, A]vowel set is under investigation, Microsoft 7 document, find (a) was enabled without matching the case .This highlighted the (a) and (A) in the speech corpus.

5.2. Mapping the vowel errors by side of vowel sets .The highlighted segments in 5.1. were then examined for binary possibilities of presence or absence of vowel errors . Those errors that were present was listed by the side of these vowel sets, in the schema of kannada vowel inventory figure 5 .The ~ markers indicated the vowel NZn and < and > markers next to transcribed phones indicated vowel length deviations. .then the next type of vowel error in 1 was explored similarly and documented, until all error types were examined for this vowel set.

5.3. Vowel error documentations In examples given above , *{t}(k)Ap{e}(i)*: in the phonetic chart 5, [iI] alternate V.V substitution is documented and in example *k{uo}(o)DbEkA{r}(dr)e* DZn is documented next to [o,O] . The speech corpus is continuously examined to identify occurrence of each error typology under consideration (>5) .I

5.4. If a particular error type is absent, for a vowel set throughout the speech corpus then no documentation work is involved for this error in the corresponding vowel set (see figure 6).

5.5. At the end of this first phase of analyses all sets of vowels are mapped with their corresponding error types extracted from speech corpora in the schema of Kannada phonetic inventory with methods above.

6. Articulatory dimensions of vowels in Kannada phonetic inventory. IPA 2005, Classifies vowel segments in terms of the articulatory dimensions of tongue *height* (vertical dimension), tongue *backness* (horizontal dimension) and *roundedness* (of lips). Vowel phonetic inventory Kannada contains a total of ten vowels whose across its articulatory dimensions (Upadhaya 1972) is given below (figure 5). The vowel system of Kannada is symmetrical when plotted in articulatory vowel chart : with 3 degrees of vowel height – high, mid -high , low (HML) , 3 degrees of vowel backness – front , central , back ,(FCB) and two states of lip roundedness feature – either rounded or unrounded (R or UR). At the end of methods 5.5, there are available mapped vowel errors in all sets of vowels for a group D1, D2 or D3. This is seen in figure 6

7. Next phase involves analyses of these vowel errors in 3 artciulatory dimensions .This provides evidences for possible susceptibility of a vowel dimension to types of vowel errors.

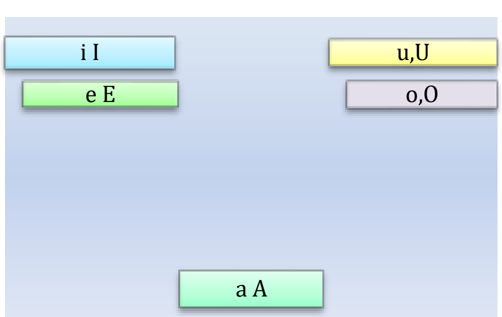

Figure 5 Kannada vowel inventory with five vowel sets based on Upadhyaya (1972)

1. Vowel errors, across their target tongue *height* (vertical dimension)-3
2. A Vowel errors, across their target tongue *backness* (horizontal dimension) -3
3. A Vowel errors, across the rounded and unrounded *lip positions.* -2

Results

1.1. Random vowel errors under consideration in this study show 3 main types of distribution in schema of Kannada phonetic inventory as shown in figures 6, 7, and 8. The participants' random vowel errors in speech corpus emerged with organized distribution.

1.2. D1 shows all types of vowel error typologies under 3 above (figure 6). Exception is an Ahifsn who has no incidence of vowel disorders (figure 5).

1.3. D2 speakers are heterogeneous.

1.3.1. An atypical D2 speaker shows V.V substitution and similar substitution of both duration and nasalization types(figure 7) .

1.3.2. 1.3.2.Another D2 speaker shows only similar nasalization Sn Sns like two D3 speakers (figure8)

1.3.4. Last D2 speaker shows normal phonetic inventory (figure5)

1.1. Two D3 speakers like a D2 speaker show only similar nasalization Sn (figure8).four other D3 speakers show shows normal phonetic inventory(figure 5)

1.2. Overall, four types of phonetic inventory patterns with three patterns comprising vowel error typologies above and the fourth pattern, is the normal phonetic inventory (figure5) seen in an AhifsnD1, a D2 speaker and four D3 speakers.

1.3. .Vowel error distributions can be grouped in two patterns.

1.4. While some vowel errors are diffused in all planes in phonetic inventory some others are not .For example, in figure 6 in D1, , both types of similar Sn and omissions and, in fig8 the nasalization similar distributions in D1, D2 and D3 in figures 6,7 and 8 are of this type. These are termed as ***Universal Vowel Error Distribution (UD***).

1.5. Rest of vowel errors show distribution in only few articulatory planes in vowel inventory .Examples include V.V substitution , diphthongization Sn, alien vowel Sns , Explicit triphthongization substitution inD1 figure 5 and V.V substitution in D2 figure 6 are of this types . These are termed as ***Restricted Vowel Error Distribution (RD).*** These are totally absent in a D2 speaker with vowel errors and two D3 speakers with vowel errors.

Thus, A beginning organization patterns of Vowel error distribution in the conversational speech data is evident in this phase overruling randomness in the corpora.

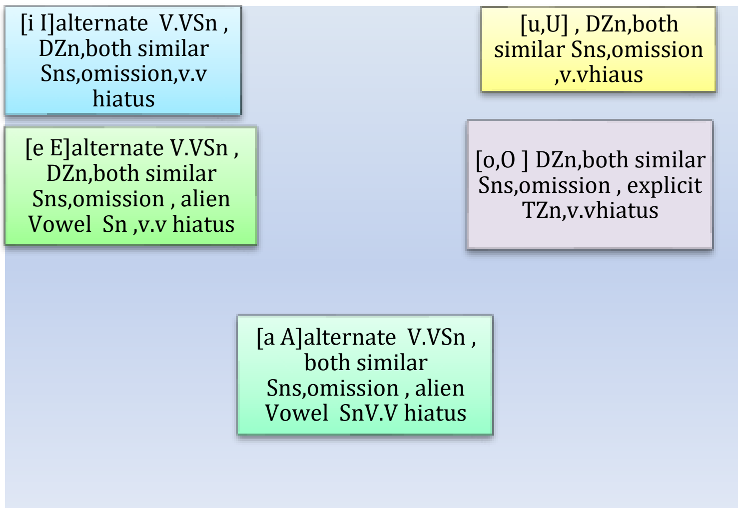

Figure 6 Overall UD, RD distributions of vowel error in Kannada phonetic inventory in D1

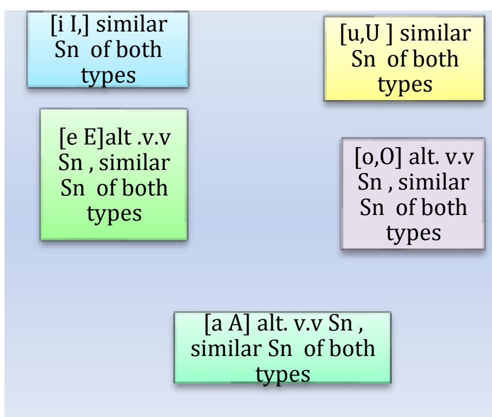

Figure 7. RD and UDS in an atypical no2 D2 speaker

2. Types of Error distributions across three dimensions of Kannada artciulatory phonetics. *It* is evident the above patterns of error vowel distributions emerge from random and variable occurrences in speech corpus in initial phase of this study. Their distributions of error typologies are different in D1, D2 and D3 in the speech corpora in initial phase of this study. Further two vowel error distributions types emerge from their random representation in speech corpus .These are the ***universal error distribution*** **and** ***restricted error distribution*.** Both these types are absent in an Ahifsn D1 speaker, one D2 speaker a four D3 speakers who conform to normal Kannada phonetic inventory. In the next phase of this study these results are further studied cross sectionally across

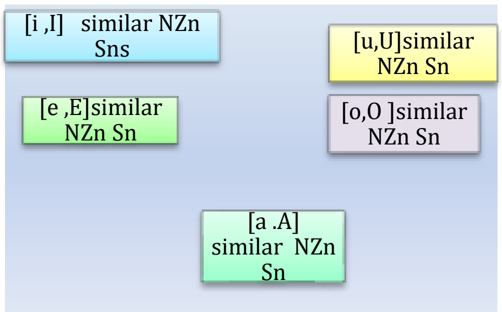

Figure 8. UDs in two D3 and one D2 speaker.

three dimensions of artciulatory phonetics: the tongue *height* (vertical dimension), tongue *backness* (horizontal dimension) and *roundedness* (of lips) (fig 9, 10, 11), for articulatory gestalt perspective to vowel error typological behaviors . None of articulatory dimensions tongues height, tongue *backness* and *lip roundedness* is free from vowel errors in D1, D2 and D3in general.

It is possible to characterize D1, D2 and D3 speech corpora based on universal vowel error distributions (UD) and restricted vowel error distributions (RD). UD patterns are seen in all three groups D1, D2 and D3.Firstly; RDs are seen only in D1 speakers and a D2 atypical speaker only. UDS of nasalization and duration are also characteristics of D1group with an exception in AhifsnD1. Secondly, D2 a heterogeneous group; however, in only atypical D2 are found restricted vowel errors. While one D2 participant shows normal vowel phonetic inventory, the other shows only UD. A third D2 speaker has atypical SNHL speech patterns that cannot be conformed into the D2 group patterns. Lastly, two D3 speakers also show only UD of nasalization like a D2 speaker. Four other D3 speakers also like a D2 show normal vowel phonetic inventory with neither RDs nor UDs. D1 speakers also comprise the vowel omissions and conspicuous V.V hiatus. In the following sections will be discussed RDs in D1 speakers .But, RDs of the atypical D2 speaker will be presented in a separate research paper.

3. Nature of RDs across the articulatory phonetics dimensions in D1 speakers.

All participants show RDS in D1 group, only one ApsnD1 shows UD of NZn in his speech corpora in .large numbers. As mentioned before an AhifsnD1 shows normal vowel phonetic inventory. All others show RD patterns. These are presented in the following sections across articulatory dimensions.

3.1.1. RDs in Tongue height dimension Figures 6, 7, 8 are also the virtual descriptions of error distributions in 3 tongue height dimensions of Kannada. Following are additional observations in this dimension .the results are summarized in figure 9.

- Alternate V.V Sn , are seen in high, high mid vowels and low vowels
- DZn are restricted to high mid and high vowels,
- TZns occur in high mid vowels only.
- Alien V Sns are restricted to high mid vowels and low vowels.

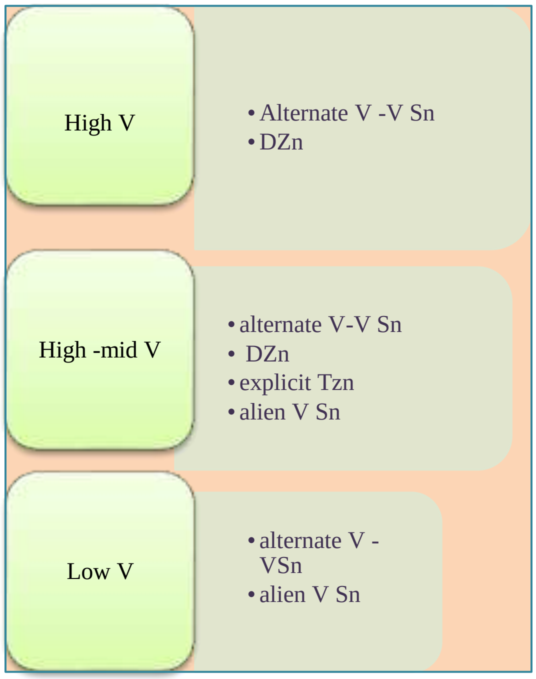

Figure 9 RDs in tongue height dimensions in D1.

3.2. RDs in Tongue backness dimension. Unlike in tongue height dimension (3.1), the tongue backness shows a better differentiation of vowel errors in D1 (figure 10) and atypical D2 .

3.2.1 Restricted errors in Tongue backness In D1-

- *Alternate V.V. Sns are seen in front and middle vowels only.*
- *Dzns are found in back vowels only*
- *Alien V. V Sns are observed in front and middle vowels only.*
- *TZns are noticed in back vowels only*

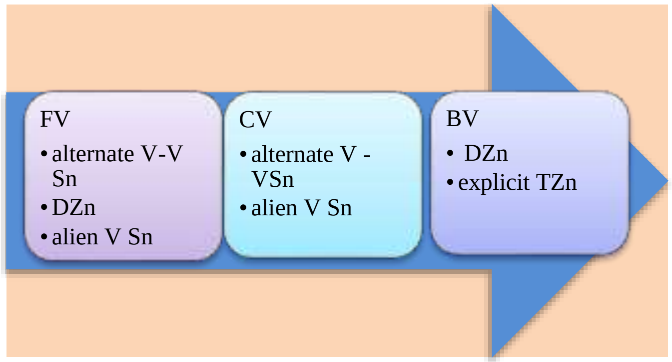

Figure 10 RDs in tongue backness in D1

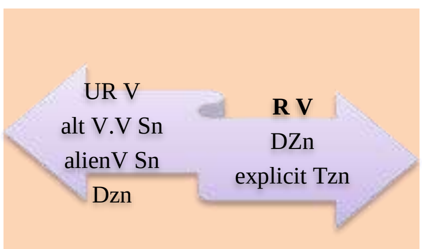

Figure 11. RDs in D1 in articulatory dimension of lip roundedness

3.3. Restricted errors in lip roundedness dimensions in D1-

- The unrounded vowels (URV) have alternate V .V Sn , alien V Sn and DZns. (figure 11).
- The rounded vowels (RV) on the other hand show only DZns, TZns, and no vowel Sns .

The results from 3.1 to 3.3 RDs demonstrate specificities of vowel error typologies across articulatory dimensions underlying random distribution in realistic nature of speech corpora .Back vowels are prone to DZn and TZn errors only. Central vowels predominantly bear vowel Sn type of errors on target vowels. Similarly, Front vowels show this pattern with addition of DZn. On the same count, rounded vowels show only DZn and TZn. UDs of duration, nasalization and omissions add to the RDs inD1. In the dimension of tongue height high mid vowels, have greater types of RDs than low vowels and high vowels. Low vowels escape the DZn and TZn, and Back vowel escape the V.V and alien vowel substitutions. None of the RDS as mentioned above is seen in either D2and D3 speakers except in the atypical D2 speaker. Finally, the D1 speakers demonstrate both UDs and RDs in general and D2 and D3 are characterized by UDs (figure12). Thus, RDs perform in a patterned manner in the three articulatory dimensions in D1. Based on the articulatory dimensions of vowels, prediction of type of errors ought to be possible with RDs in D1.

Discussion

The purpose of this study was to explore organized distribution of random, variable, multiple residual vowel errors in conversation of congenital SNHL speakers with D1, D2 and D3. Residual vowel errors are seen in the conversational corpora in D1, D2 and D3 after completion of LT- CAOSLT (long term comprehensive aural oral speech and language therapy). They are persistent, multiple types, variable with random distribution (Gayathri Vowels series I, and II 2019a and c, submission to AL) spread throughout the speech corpora. Such vowel error contexts in natural speech communication are bound to confuse the listener. for example if the word *alla* is articulated as also *ella* ,*aella*, *illa* and *alla* ,in speech communication ,then arise confusion in the listener. Here are seen random variability, and multiplicity of vowel errors for vowel [a], along with the accurately articulated vowel [a] in lexical tokens in the speech corpora. Further, some of these errors are minimal pairs in Kannada except the *aella*. Hence , the listener may be semantically perplexed at conversation , if the uttered lexicons are virtually bear the semantics of virtual vowel phonetic compositions or if it is [alla](not) itself in *ella* (all), ,*illa (*no*)* . Even though contextuality of conversations assist as some cues to some semantic inferences in at least experienced listeners, it is expected that vowels be achieved with accuracy after LT-CAOSLT in congenital SNHL speakers D1, D2 and D3. Even though the term variability of speech of hearing loss and in vowel productions are raised since the beginning of hearing impaired speech studies (Numbers, 1936) little attention is given to explore the challenging variability itself. It is the signature characteristic in speech of congenital SNHL speech in general. That, they are the outcomes of hearing loss itself and are results of degraded auditory feed back at speech production in hearing rehabilitated congenital SNHL has been the most viable explanations for nearly a century. But, it was Osberger & Mc Garr (1982) who had reasoned in the contexts of reviews of speech of D1 speakers, that, there is evidence that many of the deviations are phonetically and phonologically consistent albeit the systems may not be the same as those used by normal hearing talkers. In the present study are seen some emerging trends for consistent distribution patterns in numerous residual vowel errors in randomness, D1 D2 and D3.

Current study is motivated by *Theory of Chaos* (notes 1) with its focus on this challenging variability of vowels. Chaos' is an interdisciplinary theory stating that within the apparent randomness of chaotic complex systems, there are underlying patterns. It propounds finding the underlying patterns in apparently random data. Another justification for this study is the excessive persistence of residual vowel errors in randomness, even after the LT-CAOSLT.

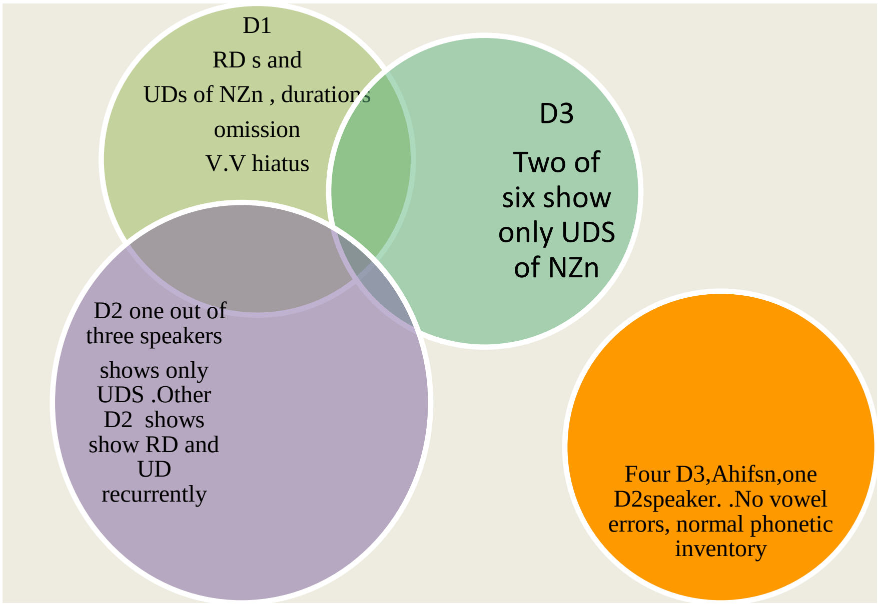

Figure12 Comparison of vowel error RD and UD in D1, D2 and D3 speakers

This investigation is pursued in the context of persistent randomness of excessive multiple types of vowel error in the realistic data of natural conversation of congenital SNHL in D1, D2 and D3. From this systematic investigation have emerged several underlying patterns of distribution of vowels errors in the broader perspective of gestalt articulatory phonetics and their types. Vowel variability is not random at least in their distribution patterns in congenital SNHL D1, D2 and D3 speakers UDs and RDs are types of distribution patterns identified in this study. It was possible to organize vowel error typologies different dimensions of Kannada articulatory phonetics. In addition, there was differentiation of these patterns in D1, D2 and D3 speakers. Number of error typologies decline with occurrence of only residual UD of NZn in vowel disordered D2 and D3, in each of three dimensions articulatory phonetics considered n this study . This means that nasalized vowel substitutions (Gayathri 2019c, II) remain as residual UDs in vowel disordered D2 and D3 speakers. Thus, substitution error typologies are persistent of all SOA types in D1, D2 and D3. .

There are also exceptions to the three groups, which comprise four D3 and one D2 like AhisnD1 show normal phonetic inventory without UDS and RD s. However, in contrast, multiple UDs of NZn and duration, RDs and omissions were found only in D1. Additionally, RDs are typical of only of D1 conversations except in Ahifsn. Basically, four types of phonetic inventories with associated vowel behavior patterns have surfaced in randomness of vowel error data in D1, D2 and D3. UDs and RDs show organized patterns of distributions with RDs showing specificity in articulatory dimensions. Phonetic inventories patterns for vowel error distribution for congenital SNHL are listed below (figure 12).

1. Normal phonetic inventory
2. Phonetic inventory with UDS
3. Phonetic inventory with both RDs and UDs
4. Alternating Phonetic inventory between 1 and 3 in an atypical - D2 speaker

Vowel Phonetic inventories with solely residual RDs are absent .RDs are seen only in D1 group and in an atypical D2 speaker. A unique pattern type 4 below is seen in an atypical D2 speaker .Distribution of RDs in D1 vary in three articulatory dimensions illustrated in figure 9, 10, and 11. RDs of residual vowel substitutions are in front and middle vowels and RDs of residual Diphthongizations and Triphthongizations are in unrounded vowels. Thus, RDs of former type are confined to front vowels and RDs of latter types are confined to rounded vowels .Two types of UD exist. This includes UDS of vowel nasalization and UDs of durational defects. Of these UDS of vowel nasalization is persistent in D2 and D3 vowel disordered speakers

From current study, additional finding is that the UDS of NZn is inferred as a common and persistent residual vowel error phenomenon in vowel disordered D1, D2 and D3 speakers after completion of LT –CAOSLT with exceptions in all three groups (see figure 12). However, they are the sole residual vowel error typologies in vowel disordered D2 and D3 speakers, except atypical D2 speaker. This means that RDs disappear and only UDS of NZn, which are nasalized vowel substitutions, sustain in D2 and D3 with overall symmetry in phonetic inventories. Further UDS of omissions and durations observed in D1 speakers are totally absent in D2 speakers. At higher advantage are 4 speakers in D3 and a D2 speaker and Ahifsn with absence of both UDS and RDS and normal phonetic inventories. The absence of vowel errors in AhifsnD1 is also confirmed in D0 (analogue body level hearing aid users) in previous studies (Gayathri 1993, Gayathri 2016, Gayathri 2019a, c). RDs are typical only of D1 speakers and of an atypical D2 speaker in this study. Residual RDS are neither front nor back predominant, which is a common vowel parameter discussed in literature of speech of the hearing impaired (Thirumalai and Gayathri 1980-82 and 1988) with standpoint of visibility of vowels. A gestalt perspective to vowel error distribution is evident in current study. For example UDs are universal in all multiple artciulatory classification and RDs are not .

This study provides for novel methods to gestalt perspective to distribution of vowel errors across dimensions of articulatory phonetics in phonetic inventories. D1 speakers have residual phonetic asymmetry with RDs distributed in their speech corpora and some UDS too. These RDs in D1 naturally show artciulatory phonetic dimension specificities and phonetic inventory asymmetries in random residual vowel errors in D1 as discussed above. Geffner's (1980) proposition that vowels [u] and [i] are more stable is not in agreement with this study. Similarly, Angelocci, Kopp & Holbrook (1964) propositions for sole preferences for either high or low vowels in D1 were not seen in Kannada SNHL D1 speakers. In those hearing statuses which auditory input are non linearly improvised such as in D3speakers , increases in accuracy for back vowels and diphthongs but not for front vowels is posited by Geers and Tobey (1992). However, in present study, in the D3 the participants who have completed LT - CAOSLT, residual vowel errors of solely UD types are symmetrical in both front and back vowels. Another study on emergence of segmental accuracy in young cochlear implant recipients, D3, has found that front and central vowels were twice as accurate as back vowels Warner-Czyz, Andrea & Barbara 2008). These authors also had highlighted that central, mid and low vowels were produced more often and more accurately. But, with its focus on participants who had completed LT – CAOSLT in conversations in this data, current study did not conform to these findings in D3. Early cochlear implantations impacts in better vowel acquisition is found by some recent studies for example in A study on D3 speakers in Persian vowels, identifies that backing of vowels were the cochlear implanted after 3 to 4 but not in those implanted within 2years (Zamani, Zarandy, Borghei, Rezai & Moubedshahi ,2016) .

Carr (1953), West and Weber (1973), Nober (1967), Smith (1975), and Geffner (1980) had reported a controversial priority of either rounded or unrounded Vowels for accuracy of vowel articulation in their analogue body level hearing aid (D0) participants . Such preferences are not found in analogue behind the ear level hearing aid users with RDs of D1 in the present study and in preliminary study in Kannada conversations in D0 too in conversations in (Gayathri, 2016).

This approach for vowel study is the first in hearing impaired literature aiming at global perspective of vowel errors in multiple artciulatory dimensions. This is an initial hyphenation to persistent mass of vowel randomness with its numerous vowel error typologies distributed randomly in the conversational corpora of congenital SNHL. With these results are speculated possible in depth organization of numerous residual random vowel errors in these speech corpora. Further probes into randomness of vowel behaviors in speech corpora of congenital SNHL for discoveries of organized patterns of vowel errors will be pursued in succeeding studies.

Conclusion

This study explored organization patterns of long presumed *vowel error* randomness of in realistic conversational corpora contexts of congenital SNHL in D1, D2 and D3 who had completed LT-CAOSLT, with motivations from chaos theory of randomness (notes 1). This problem was attacked with many novel perspectives and research methods such as the large token samplings from realistic conversation contexts, with gestalt perspective of articulatory phonetic dimensions, novel documentation of lexical phonetic conversations of transcription, Microsoft search enablers for data searching and mapping the results in articulatory phonetic inventories with multi perspectives. UD and RDs emerged whose definitions are provided in the results. They organized and differentiated randomness of variable, multiple residual vowel errors in natural conversations corpora D1, D2 and D3, while exceptions to these trends are also seen in all groups. A D0 (congenital SNHL post LT-CAOSLT , analogue body level hearing aid user) speaker from preliminary study by same author also conformed to D1 speakers.

It is evident that organized distributions patterns exist under the long taken -for -granted ‘variability in residual vowel errors for nearly a century”. An initial hyphenation to randomness en masse of residual vowel errors is successful with evidences in textual documentation under results and novel visual depictions in articulatory phonetic inventories of corresponding language Kannada. Four types of phonetic inventories with RD and UD displays emerged in this study. These are helpful in clinical differentiation of D1, D2 and D3 speakers and in identification of exceptions to the groups and atypical SNHL speakers. With this initial break- through leverage in randomness of residual vowel errors in current study, further novel probes are planned for in depth exploration of organization of vowel errors in the realistic conversation corpora of congenital SNHL in D1, D2 and D3 is planned under the parent study. Multiple applications of this novel textual and visual documentation of vowel error types and their distribution in phonetic inventories in various vowel disorders is also implicated. Further this approach captures all vowel errors in speech corpora unlike SOA such as V.V hiatus even though they are outcomes of consonant omissions. There are underlying regularities in random vowel errors of conversational speech corpora in congenital SNHL D1, D2 and D3.

Limitations

Outcomes of results from D2 are heterogeneous due to speech atypicality in a D2 speaker identified in this study . This demands more number of subjects in this group.

Notes 1

“One of the remarkable things to emerge from the science of chaos is <u>that under certain conditions, ordered, regular patterns can be seen to arise out of seemingly</u>

random, erratic and turbulent processes. Chaos theory is only one of the many areas where the appearance of patterns acts as a powerful engine driving scientists in an unending study of nature and the human condition. Chaos is the study of how simple patterns can be generated from complicated underlying behavior. ...Chaos theory does not emphasize the inherent disorder and unpredictability of a system. Instead, chaos theory emphasizes the order inherent in the system and the universal behavior of similar systems" Chaos -- Patterns In Nature, an on-line book - Nature's Web Of Life *www.patternsinnature.org/Book/Chaos.html*

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4

Embedded Regularities of Phonetic Vowel - Shifts under the Surface Randomness of Residual Vocalic Substitutions in Conversational Speech Corpora of Congenital SNHL with Contemporary Hearing Devices- IV

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Abstract

Current study is a first attempt to the novel application of linguistics based Vowel -Shift concept to the predominant and persistent random variable residual vocalic substitution (Sn) defects in congenital SNHL. The same was modified and adapted for study of substitutions in congenital SNHL conversational corpora termed as VSAPD device .Emerging from this research surface similar and dissimilar vowel Sns types and structured Vowel - Shifts patterns in the latter types . These embedded vowel shift processes differ between the speech in analogue behind the ear (BTE) hearing aids users (D1) ,programmed digital BTE hearing aids users (D2),and the cochlear implanted D3. While in D1 speakers multiple vertical Vowel - Shift (V-S) patterns are identified, the D2 speaker have shown limited and an additional interesting atypical Vowel -Shift patterns .The cochlear implanted group D3, two D2 speakers, an adult spsnD1 and AhifD1 speakers have no Vowel -Shifts in their speech production. Overall, 7 types of vowel shift patterns are materialized from random vocalic Sns with presence or absence of dissimilar vowel Sns. Possible vertical compression of frontal and central articulatory space is speculated with rigidity of posterior lingual movements at vowel substitutions. It is suggested that this new handy VSAPD with its bases of vowel shift theme drawn from linguistics has practical clinical and research implications in future.

Keywords vowels, Substitutions, congenital SNHL, analogue behind the ear level hearing aid, programmable digital BTE, cochlear implant, articulatory phonetics, conversation, therapy, deaf, analogue body level hearing aid, vowel shift , mergers , articulatory space , misarticulation

Introduction

Vowel substitutions error typologies are common vowel errors in congenital SNHL (Hudgins 1934, Numbers 1936, Gold 1980, Nober 1967, Ling 1976) in D1, D2 and D3 speakers (Verhoeven, Hide,, Maeyer, Hide & Gillis, 2016. Osberger, & Mc Garr1982 Baudonck, Van Lierde, Dhooge & Corthals, 2011, Sfakianaki & Nicolaidis 2016, Smith 1975, Gayathri 2019c, d; II, III,LII jl). The vowel substitutions are excessive, extensive and persistent in analogue BTE hearing aid users (D1), digital hearing aid users (D2) and to relatively minimal degree in D3 speakers as residues even after long-term comprehensive aural oral speech and language therapy (LT-CAOSLT). Under the vowel error typological classifications (Gayathri 2019 c), they are of six types, with random variability as their characteristic feature. From conversational data it was found that congenital SNHL has a continuum of embedded vowel segments from normal vowel articulation to many error typologies with random variability's in realistic natural speech corpora was identified (Gayathri 2019 a, b ,c, d vowels series I, II and III)in previous studies. Vowel articulation variability or randomness is the signature of congenital hearing-impaired speech .Variability is confirmed in substitution, omission, addition, and other error typologies (Gayathri 2019, c, d II, III).

Variability of speech defects in general in hearing impaired articulation is also reported by many investigators and in review papers(Osberger & Mc Garr 1982 ,Thirumalai& Gayathri 1988 ,1982, Gayathri 2016 , Gayathri 2019 a, b,c d ; Svirsky & Chin (1998), Verhoeven, Hide, Maeyer & Gillis 2016). . Recently, Verhoeven, Hide, Maeyer & Gillis (2016) assessed Belgian Standard Dutch vowels in cochlear implant and hearing aided children and in control population with normal hearing. They portray an array of acoustic variabilities in vowel articulation. Significant intra subject variance was seen in both cochlear implanted and hearing aid users**.**

This study explores bulk of vowel substitution defects in congenital SNHL speech corpora and their variations for many key reasons. Even though hearing impaired research spans more than 80 years the classic phenomenon of *Residual Vowel Substitutions* are not overcome after long term comprehensive aural oral speech language therapy (LT-CAOSLT), while additions and omission vowel errors repair and disappear in AmssnD1and some AspsnD1 , D2 and D3 speakers(Gayathri 2019,c). Their abundances and randomness are challenging even to a trained listener to decipher the intended message by the hearing impaired of congenital SNHL speech. The problem gets even more challenging in contexts of minimal pair utterances .For e.g. The same word *illa* (not having) is uttered as *ella* (all), *alla* (no, not) and also as multiple patterns of coalesced word samples *i>~lla*, along with target word utterance *illa*. Not stopping here, these ambiguous word clusters expand with adjoining minimal pairs or words in conversations. At expression of *ella* (all) as target word similar word - complex may emerge. Hence, *alla* means no, not, *alla* also means *ella* (all) when vocalic substitution [a/e] , has taken place in the second word . In addition, multiple Sn occurrences may be encountered in same word, complicating this issue .e.g. : ***enna***, for ***all**a* or even *e**nne**(unintelligible or closer to eNNe –oil)* for *ella.* It can be observed how just two target minimal pair lexicons vary continuously in spoken conversation with defective articulations and normal articulations of same phonetic segments. For Kannada language Ramachandra (1999) has illustrated more than 45 minimal pair vowel contrasts in his book descriptive Kannada phonetics. In addition to semantic confusions that they lead to, vowel Sn errors are most common error in congenital SNHL, it is persistent residual error (Gayathri 2019 II, LII jl) compared to omission or additions . Beyond all these, the congenital SNHL who have completed LT-CAOSLT have the potential to also articulate accurately all ten Kannada vowels (Gayathri 2019 I, LII jl). For these multiple reasons, examination of random Sn error is important. Even though, conversational context and familiarity with the speaker or clinical experiences to some extent help decode appropriate meanings to an extent, they do interfere with fluent communication task. Such ambiguities existing in multiple word structures within a speech corpus interferes with fluent dyadic conversation. In addition, for Indian multilingual contexts Sns vowel errors are considered to contain 6 patterns in conversation data (Gayathri 2019 II, LII jl). . Hence, persistent vocalic substitutions and their random nature in congenital SNHL speech are a challenging problem in speech language pathology even though Sns and their variability are attributed to poor auditory feedback in congenital SNHL. A last and vital thrust for current study comes from *chaos theory in science*. The science of chaos emphasizes that under certain conditions, ordered, regular patterns can be seen to arise out of seemingly random, erratic and turbulent processes. Thus, it was hypothesized that the plentiful chaotic vocalic substitution tokens in conversational speech corpora of congenital SNHL dispense possibilities for identification of some inherent regularities. A first attempt of application of this Vowel -Shift concept (Gordon 2005 , Labov, Malcah & Richard 1972 , Labov 1994, Hoenigswald 1960) drawn from linguistics to understand the common, random vocalic substitutions can be seen in current study. The results are compared amongst users between different hearing devices stated here in the congenital SNHL population.

Methods

This study is a part of ongoing parent study on conversational speech of congenital SNHL begun in 2007 .The parent study contains 18 congenital subjects who had completed intensive long-term oral-aural speech and language therapy. Their mother tongue and regional tongue was Kannada. .They also wore three different contemporary hearing devices: analogue BTE hearing aid, digital behind the ear hearing aid and the cochlear implanted named as D1, D2, D3 hearing domains(see figures 1,2,3,4) . Table1 provides clinical details of 18 participants in this study.

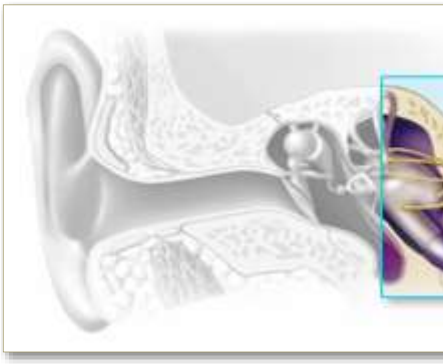
Conversation section coined as TELS HI /Kannada (Thirumalai and Gayathri 1982, 1988) after many

1. Apsn_Domain1
2. Aspsn_Domain1 n=2
3. Amssn_Domain1
4. Ahifsn_Domain1
5. Cpsn_Domain1
6. Cmssn_Domain1
7. Apsnsib2 Domain1
8. Aspsnsib2 Domain1
9. Aspsn D2 Domain- n=3
10. D3 Domain - n=6

All participants except CpsnD1 and CmssnD1 had completed speech and language therapy
D1= Analogue BTE hearing aid user, both ears, n=9
D2=Digital programmable hearing aid user. All were children, both ears
D3= Cochlear implanted (in one ear), age @sampling = 8-10 years, post speech and language developmental period
Sib2=second congenital SNHL sibling in family
C, D1= child, ongoing speech therapy, and language experience for 7 years, parallels with child D3
A=Adult
Clinical User friendly acronyms for degree and type of SNHL e.g. psn=profound SNHL, hifsn=high frequency SNHL, mssn=moderate severe SNHL

Table1. Clinical details of D1, D2, D3 participants in this study, n=18

years of clinical use, was administered in a silent room in face-to-face context. The same was recorded with high quality Sony digital audio recorder. IPA transcription was adapted with fine attributions where needed for phonetically abnormal word units up to their utterances. Further details of methodology adapted can be seen in Gayathri (Vowel I, 2019). Perceptual approach was adapted to make judgments of vowel phons.



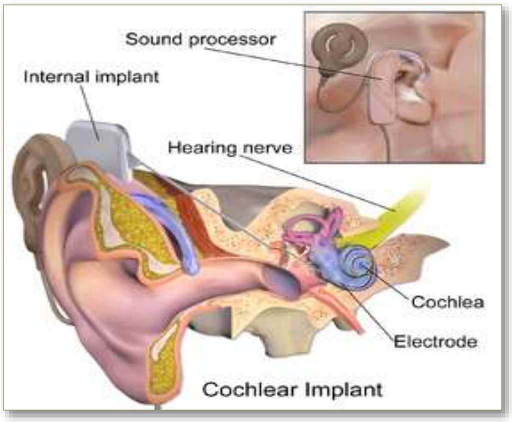


Figure 1. Affected Parts of Ear in Congenital SNHL.

Figure 2: Domain 1, D1, Analogue behind the Ear Hearing Aids

Figure 3: Domain 2, D2, Programmable Digital behind the Ear Hearing Aids

Figure 4: Domain 3, D3, the Cochlear Implanted

Table 2 Examples of Vowel Sns in D1 group

{ə}(a)pp{E}(a)
pAp{ə}(a)
b{aeae}(e).i(- L)’)gg{ei<}(e)
t{E}(a){k}(rk)Ari
{E~}(a){g}(ng)aD{I>}(I)li
m{aeae}(E)lE
{ə}(a)nup{a~}(a)m{a~}(a)
n{aeae}(A)ku
(t}(s)ar{e<}(i){ty}(t)A
{t}(n){A}(a)R{EE}(i
n{uo>}(O}(T)U
b{aeae}(e)nk{i~e<}(i)
{g-}{uuO}(o)ttu
{uo<}(u){m<p}(pp){A}(i)Tu
t{uoↃ}(o)risabEda
mADut{aeae}(E)ne
y{e}{i}{D}(Dl){ei}(i)
pu{t}(st){E>}(a)ka
{b}(m){ou<}(o)sar{u-). k{uoↃ}(o)DbEkA{r}(dr)e

A novel approach to document lexical phonetic transcription of the conversation corpora was adapted. Word by word transcription was undertaken systematically .In each lexical transcription, flower brackets are used for subject’s phonetic segment misarticulation with target phone written in regular brackets adjacent to it. E.g. if [ADalla] is target lexicon, misarticulated phones within this target lexicon was documented as [A{d}(D)a{l}(ll)a].IN [A{d}(D)a{l}(ll)a] those phones in flower brackets are defective : {d}and {ll} . Their target phones are [D] and [ll] are by their side in regular brackets. Overall, they provide for phonetic and phonotactic contexts of the subject’s articulated phonetic segment and also the target phonetic segment simultaneously. By skipping flower brackets participants target word is read, and by skipping regular brackets, misarticulated word is read. By observing, the units within square brackets judgments were done in word context. Thus, the phonetics of target phons and participant’s phon production can be compared in within a single lexical boundary with parallel misarticulations and target phons with this new documentation approach to lexical phonetic transcription of conversation (table 2) . The raw transcribed data comprised six types of alternate vowel on vowel substitution, nasalized vowel substitution, and varied duration substitution, diphthongization, explicit Triphthongization, consonant substitutions (Gayathri 2019c). First step for vowel shift involved data structuring demarcations of substitution errors. This was followed by mapping error tokens of substitutions on schema of Kannada phonetic inventory. Last step involved marking with directional arrow the movement of substitution error off the target phone for the specific error .The process was continued for all extracted tokens.

Table 3 tabulation of extracted dissimilar vocalic substitution tokens extracted from conversation speech corpora			
Sl no	Target vowels -set	Examples of Extracted Substitution tokens for D1	Examples of Extracted Substitution tokens for atypical D2

1	a	E,ae rare-i,,o, u,a~,A~,AA>,a<	[ɑ-] Open back unrounded vowel,a~
2	i	E,ei,ie,a rare- u,I~,I>, i<	ʌ
3	e	I,ei, ie, aeae rare- o,a.ae eo,,,iA,Eae, I, A,E~,e~,EE>	nil
4	u	uo,ou,uↄ uoↄ rare –o,u~,U>,u<	Nil,u~
5	o	uo,ou,<O,O>	Ↄ,o~
		These vowels were also randomly coalesced	

Table 3.Examples of Vocalic Sns tokens extracted from data in D1and an atypical D2speakers

1. Definition of vowel shift. Vowel shift is defined in current study defined as movement of substituted vowels with respect to its target phons in articulatory space indicated schema of target language phonetic inventories or in the vowel shift artciulatory phonetics diagram (VSAPD) which will be illustrated in later sections. The different vowel heights in articulatory schema are called as vowel floors in the schema. Each vowel floor is intended for pooling substitution tokens of both long and short vowels in this study. The term *vocalic vowel shifts* is adapted in current study in a broader perspective. The reason being , vowel profiles of some SNHL participants contained in addition to ten vowels of Kannada , deviant vocalics such as uo ,ei,u<O. In current study these vowel shifts are also plotted on VSAPD diagram prepared on the bases of articulatory schema of Kannada vowels to

facilitate visual observations of vowel shift movements, see step5.

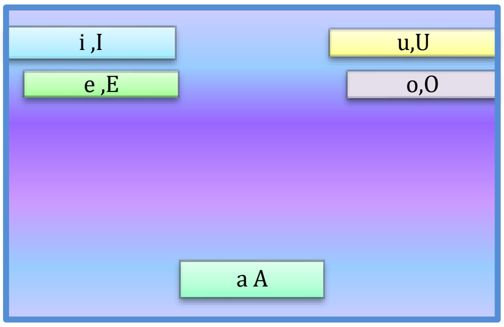


Figure 5. Diagrammatic Schema of Kannada phonetic inventory adapted VSAPD each floor with combined LV and SV.

2. Data structuring and data demarcation. It is logical to foresee that no vowel movements can be assessed in duration and nasalization substitutions, which are the similar vowel substitutions. The similar vowel Sns were hence excluded as no vowel movements for these types of artciulatory errors can be logically found. The vowel Sns and the targets comprise same articulatory feature except the NZns and duration defects. On similar bases, consonant Sns are eliminated. Further, each vowel set for comparison included. Due to creation of five vowel sets in current investigation, each comprising long and short vowels (step1) , from ten Kannada vowels in Upadhyaya's (1972) phonetic reader , no long versus short vowel comparisons were possible (see 5).

3. Extraction of Sn Data the repository of substitutions was sorted to vocalic substitutions comprising of diphthongization, triphthongization, nasalization, altered duration vowel and coalesced error typologies from consonant substitutions (table 3).

4. Data retrieval of vocalic Sn error tokens extracted from word units at transcription for each hearing domain. Some examples of these vowel error tokens D1can are seen tabulated in table 3. Other D2 and D3 speakers showed only NZn Sn .

5. Data Mapping of Substitution Errors on schema of Kannada phonetic inventory. This step is a novel design of current investigation defined for the sake of clinical purposes and visual depictions along with conventional solely textual documentations in linguistics. The extracted vocalic or vowel substitution phonetic errors tokens were marked on the Kannada VSAPD diagram with five vowel sets. Long and short vowels are pooled as one vowel set . This is because, logically no vowel shifts between long and short vowel can be predicted . Ten vowels of Kannada subsequently form five vowel sets,with five vowel floors ,for marking of vowel shift movements . The bases for preparation of this diagram in this study is on the bases Upadhaya 's (1972) studies in Kannada articualtory phonetics.The VSAPD diagram facilitates for visual inspection of vowel shift movements along with evidences of their descriptive textual documentation at analyses . With creaton of five sets of vowels , long versus short vowels are also not compared in this study on vowel shifts .Thus ,there are three are a total of five floors distributed in front ,central and back articulatry parameters in VSAPD dreived for Kannada . They are also considered in this study as representation of five sets of vowels in artciulatory space .. figure 5 serves as basic VSAPD for mapping and marking Sn errors . Identification of taget vowel and subtituted vowel on vowel floors is th first step , called as data mapping . When alien vowels enroach as vowel subtitutions, then additional floors corresponding to that vowelbased on IPA vowel chart is incorporated in this VSAPD diagram. That means alien vowels Sns demand additional floors in VSAPD figure 5 with its bases of Kannada phonetic inventory .

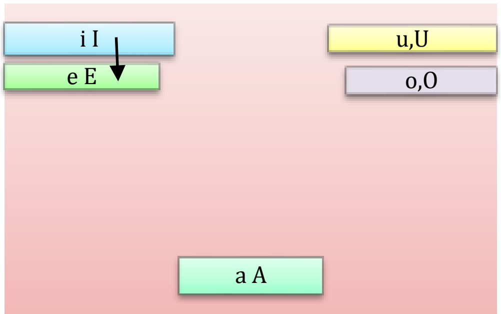


Figure 6 illustration of vowel shift in example step 6 in the VSAPD diagrammatic schema of Kannada.

6. Marking the vowel shifts of the substitution errors with directional arrows. They indicate direction of movement of substituted vowels from its target vowel points on VSAPD . For example ,if [e] is substituted for vowel [i] then a downward arrow begins from [i],the target vowel to substituted vowel [e] in VSAPD .This means vowel[i] has moved from front high vowel to front high mid vowel; i>e (figure 6). This marking on separate VSAPDS is completed for all dissimilar vowel Sn extractions retrieved for each group in step 4, each group D1, D2 and D3. Based on V-S types the directional markers may move upward, downward ,forward , backward in VSAPD .

7. Analyses of vowel shifts Vocalic Substitution errors are examined across artciulatory floors mapped in VSAPD of D1 (figure 7) with directional markers. This involved identification of movement patterns of vocalic substitutions from their corresponding target vowels as upward or downward, or horizontal front or back movements (see figure 7), or both. In total, 5 sets of vowels each with their long and short vowels are analyzed. They include three vowel floors comprising high, high mid and low vowels of Kannada in front, central and back in schema of Kannada articulatory phonetics which corresponds to vowel floors in articulatory space. Vowel shift patterns are described in descriptive and historical linguistics for sound changes in languages (Hoenigswald 1960, Gordon 2005 , Labov, Malcah & Richard 1972, Labov, 1994). The vowel movement patterns were inferred as Vowel –Shifts (V-S) and their patterns are assigned appropriate labels that are in use in linguistics. The data driven results are thus documented and interpreted for each group. Comparisons are then made of Vowel -Shifts between D1, D2, and D3.

Results

There emerged from the vowel shift analyses from VSAPD, multiple types of vowel shifts in D1(figure 7). They are identified in D1 and are absent in typical D2 and D3 speakers .They are also present in an atypical- D2 speaker .Vowel –Shifts patterns in D1 included adjacent vowel shifts, mergers , drag shifts and chain shifts .These are described with corresponding examples in following sections .

Similar vowels substitutions and dissimilar vocalic substitutions As expected, substitutions (Sns) of nasalization and durations, show no movements or shifts in VSAPD .They are the called as similar *vowels substitutions* with zero vowel shift. Those vowel tokens which showed vowel movements were called as *dissimilar vocalic substitutions* with vowel shifts. Thus, only the latter tokens are considered for Vowel -Shift movements in current study. Vowel elements from *coalesced dissimilar vocalic Sn* errors were also considered for mapping on VSAPD of D1.

1. Vowel -Shift patterns in dissimilar substitutions in D1.

Movements of Sn errors are logged with reference to target vowel location in VSAPD. These are represented in figure 7. An array of movement patterns of erred vowels can be seen in figure 7. Adjacent shifts, Chain shift (‡), drag shifts and mergers were major types of Vowel -Shifts, conventionally reported in linguistic literature. Along with these were mergers in high and high mid positions. An additional tern *oblique vowel shift* is coined on the bases of results 1.4. Crowding effect of phons particularly in frontal oral articulatory space, and creation of new floor in anterior part of VSAPD were other observations.

1.1. Vowel -Shift patterns are asymmetrical. Overall observation from figure7 is that Vowel -Shift patterns are asymmetrical in front and back articulatory space.

1.2 More often Vowel - Shifts are in **vertical direction** in D1.

1.3. Vowel floors in front and middle are at both receiving and dispatching ends. Locus of highest number of vowel shift patterns is in [e]and [a]. This means that vowels from other vowel floors drop into a specific vowel floor. At the same time, it sends its vowels to other vowel floors, in addition to these high mid [e] shows mergers, indicated by broken outlines of vowel floors , which is explained in later sections

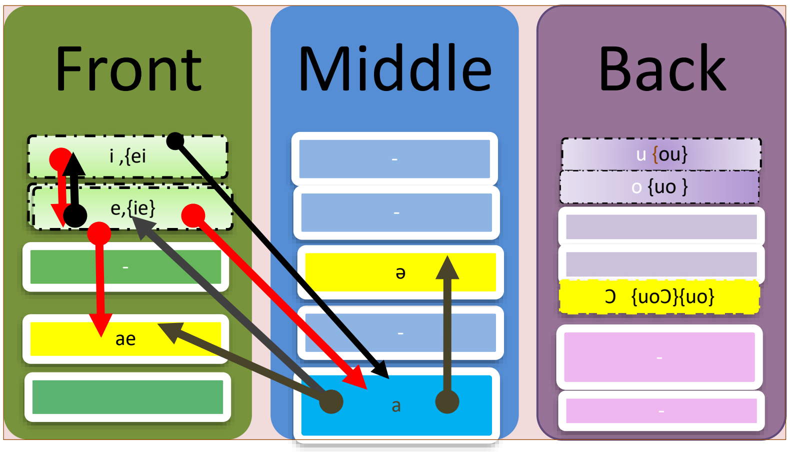


Figure 7. Vowel shifts and mergers in VSAPD of D1

1.4. Chain shift (‡). Anterior high peripheral vowels drift to high- mid vowels i>e. High- mid vowels drift to low-mid vowels e>ae(Figure 6) . This pattern of successive vowel movements is termed as *chain shift* (‡). In historical linguistics, a chain shift is a set of sound changes in which the change in *pronunciation* of one speech sound (typically, a phoneme) is linked to, and presumably causes, the change in *pronunciation* of other sounds as well. They are successive vowel movements hence they are also called, as *Synchronic Chain Shifts* are a pattern in Vowel(V) behavior whereby certain sounds are promoted (or demoted) stepwise along some phonetic scale (Synchronic Chain Shifts in Optimality Theory ,see Kirchner). They are identified only in front part of oral cavity in D1.Overall they refer to successive movements of vowels in adjacent vowel floors in the VSAPD of D1 in figure 7. A further probe into each transcribed profile of D1 participants revealed that this pattern is seen in adult profound congenital SNHL participant i>e>ae. Oblique movement of low vowel [a] to front, low mid [ae] was a persistent phenomenon in many D1 speakers in AspsnD1.

1.5. Adjacent shift The uttered defective vowel Sn jumps only to nearby floor in VSAPD For e.g. [i] to vowel[e](figure 7), and the converse in D1. Some adjacent vowel shifts across floors in VSAPD have forward and reversal markers in D1 .eg:e>i; i>e and a>e, e>a in figure, 7 .But vertical downward adjacent shifts are common than vowel shifts in reverse directions in D1 .

1.6. Drag *shift*. In this pattern of vowel shift, erred vowels skip one or more floors from its target position. e.g. i > ae; a>i.

1.7. Oblique Vowel Shift is a new term introduced in this data driven results shift a>ae; e>a fig 7. Vowels move simultaneously vertical and horizontal floors. however some Vowel -Shifts in anterior oral cavity bear two characteristics ,.firstly are the vertical movements .secondly are found vertical downward forward drift in anterior oral cavity [e] to [ae] : e>ae. The common descending vertical downward Vowel -Shift patterns are expressions of *Vowel Reduction.*

1.8. The chain shifts, adjacent shift oblique vowel shifts and drag shifts are absent in posterior vowels in D1 speakers.

1.9. All the above shifts are more frequently in downward vertical direction. These are confined to anterior oral cavity in D1 participants.

1.10. Solely horizontal shifts from anterior to posterior oral cavity are not seen in D1.

1.11. Low central vowels drift to mid central vowel [ə], a>ə. They also show vowel drifts to low mid vowel [ae] a>ae .Both these are patterns of *Vowel Reduction in* vowel shift processes.

1.12. New vowel floors in VSAPD. There are evidences that vowel [a]shifts to mid vowel [ə] or [ae] e>ae, a> ə with creation of new floors. In one participant Apsnsno2D1 is creation of new floor for Ɔ, through o>uo Ɔ.

1.13. Mergers are conceded as loss of phonological or phonetic discreteness. Two adjacent floors lose their distinct phonetic margins and merge to form corresponding diphthongs .These are observed in both front and back vowels in adjacent high and high mid floors, which are marked with broken outlines fig 6, in D1. .In back vowels, it is the only vowel shift pattern. However, only a CmsssnD1 has shown sporadic adjacent downward vertical vowel shifts in back vowels u>o. This feature of merger is symmetrical in both front and back of oral cavity.

The frontal mergers repair with greater language experience and they get eliminated from speech corpora in D1 participants. However, the posterior mergers remain in speech corpora. . E.g. in Aspsn no2D1 frontal mergers repair unlike in ApsnD1. Posterior lingual activities are hence persistently more constrained than anterior lingual movements lacking in discrete vowel floors at vowel misarticulations.

1.1.4. The impact of creation of new vowel floors and multiple chain shifts and mergers in front part f VSAPD creates a crowding effect in relative to target Kannada phonetic inventory (figure 7)

1.15 .Another inference that can be made from VSAPD in D1 is that dissimilar Sns and mergers are confined to corresponding unrounded front or central vowels set apart from rounded back vowels .There is no diffusion of roundedness phonetic aspects in residual vowel Sns in D1 .

1.16**. V-S hubs in VSAPD D1.** VSAPD in D1 is not only asymmetrical but also maximum number of v-s patterns and movements are seen in front of VSAPD , followed by middle and back sections of VSAPD .

2. Vowel -Shift patterns in D2speakers

Table 4 .Examples of V Sns in an atypical-D2
with recurring alternating speech bit types 1and 2 spread throughout fluent conversation and narration .

speech bit type 1 with vowel disorder contain both similar an dissimilar vowel Sn s	speech bit type 2 with no vowel disorder
yA:k{ʌ~<}(E)ndre h{Ɔ}(o)ge h{Ɔ~<}(O)gbOdu En{ʌ~}(a)nta Ad {ɒ ~<}(a)kke y{A~<}(A)kEnta n{a<~}(A)nyAke	No examples of similar or dissimilar vowel Sns

D2 speakers are heterogeneous in their vowel performances. One out of three adult congenital SNHL AspsnD2 speakers presents normal vowel articulation. Another AspsnD2shows only similar Sns of NZn. Thus, both these D2 participants show normal VSAPD like figure 5. However, a last AspsnD2 has two recurring alternating speech cluster patterns . These are termed as speech bit types 1 and 2. Speech bit type 1 comprised of random vowel errors of both similar and dissimilar vowel substitution types along with prototypes of normal vowel articulations. His other alternating speech bit type 2 comprised of normal vowel articulations .Hence; he presents variability in vowel articulations at conversation in multiple manners. Firstly, he has continuously alternating speech bit type 1 and type 2 causing vowel variability between them. Secondly, in speech bit type 1 he has normal vowels, dissimilar vowel Sns, similar vowel Sns and coalesced Sns. His data is analyzed for patterns in vowel shift. Examples of dissimilar Sns in both sets of speech bits is given in table 4 and vowels shifts are mapped in VSAPD8 and8.1 for two types of alternating speech bits

3. V-S patterns in two different speech bits in atypical- D2 speaker

3.1. Vowel -Shift patterns are asymmetrical in front and back of VSAPD in general.

3.2. Some vowel floors have absent vowel shifts . These are confined to both front and back high floors in VSAPD

3.3. Horizontal oblique Vowel -Shifts and vertical downward drag- shifts were identified in vowel affected D2 speaker.

3.4. New vowel floors .Creation of new vowel floors for [ʌ,ɔ];[ɒ]

3.5 Drag shift Downward drag shifts in posterior part of VSAPD o>Ɔ from close mid to open mid both being rounded vowel back open mid unrounded vowel jumping to mid -back position in IPA .

3.6 Horizontal backward Vowel –Shifts. A *Pull back* effect VSAPD correspondingly in oral cavity. *E*>ʌ, a>ɒ back open rounded vowel, a>ʌ back open mid unrounded vowel.

3.7. Mergers are not seen in VSAPD of D2

3.8. **V-S hubs in speech bit 1**. Hubs of occurrences of vowel Sns errors are in posterior articulatory space. The vowel floors in posterior part of VSAPD figure 8 , in atypical-D2 is always at the receiving end .Vowels are dispatched to posterior oral articulatory space. In addition, vertical V-S are also in posterior VSAPD .Directions of V-S movements are also unidirectional .

3.9. There are no vowels floors with both dispatching and receiving vowel shifts in VSAPD fig 8. All V-S are unidirectional in speech bit type 1.

3.10. Uni- directional ‘**pocketing ‘of erred vowels** in low back area in VSAPD. Vowels are dragged from upper posterior floor or low central vowels, or even front high mid vowels to posterior oral cavity .*Pocketing of erred vowels* happen within open mid floor to open-low floor in posterior VSAPD .

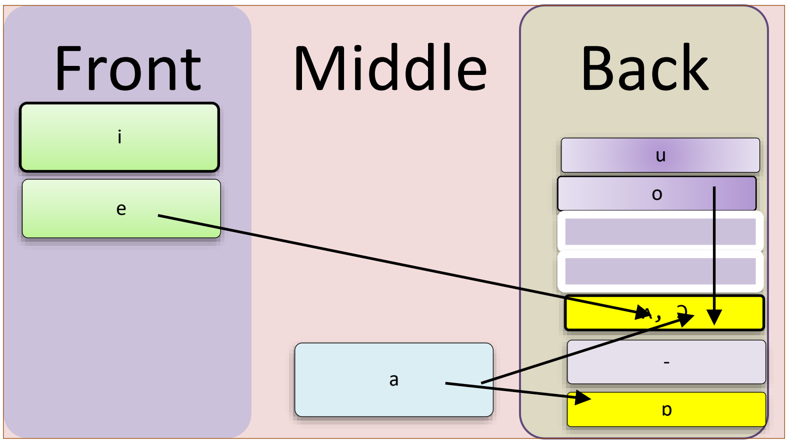


Figure 8 Vowel shifts in VSAPD of speech bit type 1 in atypical -D2 speaker

3.11. in contrast to D1 (figure 7 versus figure 8, 1.15) there occurs change in lip roundedness in Sns to [a], a>ɔ due to horizontal drag shifts in backward directions in VSAPD.

Thus, this atypical D2 speaker presents both Zero vowel –shift and vowel shifts with similar vowel Sns in recurring speech bit types 2 and 1 respectively.

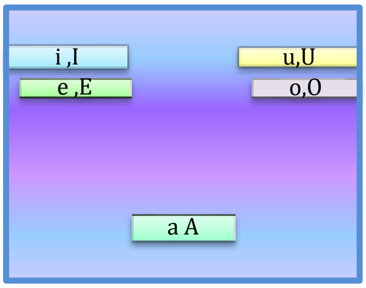


Figure 8.1 VSAPD of speech bit type 2 aligned for immediate comparison

the VSAPD is also helpful in intra Subject comparisons . Thus, D2 speakers in current study are heterogeneous in overall vowel shift parameter which included one participant with zero vowels shift and associated similar Sns. The second participant has zero vowel shift with no associated similar Sns .last participant is the atypical -D2 speaker above with two sets of VSAPD. The first two participants conform to VSAPD in figure 5 or 8.1 which are same.

Vowel- shifts in D3 speaker

Zero vowel- shifts are identified in all six D3 speakers. Of these, two have Zero Vowel- Shifts additional similar, NZd vowel similar Sns. Their VSAPD will thus conform to figure 5 or 8.1 as a group.

Discussion

Findings from earlier studies from conversation corpora (Gayathri 2019, I, a) are that a vowel could comprise an array of Sn errors and that they are variable. The residual vowel defects were hence a variable phenomenon .Of these substitution defects were predominant and persistent (Gayathri 2019, I, c). The purpose of this study was to explore with qualitative approach inherent regularities in randomly occurring residual vowel substitutions (Sns) occurring in large number, in the conversational corpora in D1, D2 and D3. For this purpose, vowel shift concept from descriptive linguistics was adapted. The VSAPD diagram of vowel shift for Kannada is originated for practicality purposes in this study with its phonetic bases from Upadhyaya (1972), with markers of vowel error directional movements establishes itself as a handy device to assess characterization and patternization of vocalic substitutions which is bound to have clinical implications in congenital SNHL residual vowel substitution analyses . This diagram with its methods is termed as VSAPD. With these new methods, overall, inherent patterns of vowel shifts underlying random vocalic Sns in the conversational corpora of congenital SNHL who had completed long term comprehensive aural oral speech and language therapy (LT-CAOSLT) are unearthed in this study. Their occurrence in large numbers distributed randomly in the corpora are a challenging phenomenon .Their variability's are reported since 1936(Numbers) in hearing impaired literature. With motivations from *Chaos Theory* of randomness some regularities under the wrap of randomness was hypothesized, which initiated qualitative exploration, sorting of vocalic substitution errors, and with application of concept of vowel shift from field of linguistics. For this purpose, visual shift was defined, and a practical visual vowel-shift articulatory phonetic diagram (VSAPD fig 5, 6) with markers was evolved in target language Kannada.

Through methodological adaptations illustrated in current paper, two types of vowel Sns are first classified for practical purposes of mapping the vowel movements in VSAPD. These comprise the similar vowels Sns which deserve rejection in study of vowel shift movements due to overall similarities in articulatory dimensions to target vowel which imply absence of vowel shifts except the nasalization and duration which cannot be represented in this vowel shift device. The second types of substitutions are the dissimilar vocalic Sns with alternate vowel phon in place of target phon in a lexicon. The dissimilar Sns make possible marking in the current (VSAPD fig 5, 6, 7, 8) with directional markers from target vowel floor to Sd (substituted) error vowel floor. When alien vowels to Kannada are Sd then, corresponding new floors are introduced in to the VSAPD, with reference to IPA. After completion of marking all dissimilar vowel Sn tokens extracted from a corpus it is possible to visually examine VSAPD and make multiple inference on vowel shift patterns of dissimilar vowel Sns. Types of vowel shift patterns , direction of vowel shifts, creation of new vowel floors and symmetry of VSAPD (see fig 7 and 8, sections 1 and 2). From 1 and 2 it was inferred that there exists inherent patterns of dissimilar vocalic Sns.

Synopsis of results is that the following overall vowel shift patterns are inherent in random vowel substitution errors in congenital SNHL participants D1, D2 and D3.

1. Zero vowel shift and absent similar vowel Sns in AhifsnD1, an AspsnD2 , four D3 speakers ,and unique AspsnD2 in one of two types of speech bits .It is also inferred for AhifsnD0 (the analogue body level hearing aid user in preliminary study, who had showed zero vowel errors (Gayathri 2016)-normal
2. Zero vowel shift and similar NZd vowel Sns in an AspsnD1, another AspsnD2 and two other D3 speakers
3. Vowel shifts with mergers and similar vowel Sns in ApsnD1, CmssnD1, another AspsnD1
4. Only vowel shifts and similar vowel Sns AspsnD2 in one of two types speech bits
5. Only mergers AmssnD1 with similar NZd vowel Sns
6. Horizontal back focus vowel shifts and similar vowel Sns n atypical AspsnD2 in one of two types speech bits
7. Vertical vowel shifts in front and central vowels and similar vowel Sns in ApsnD1, CmssnD1, another AspsnD1

From these findings are evident patternizations of vowel substitutions errors with multiple parameters .D1 and D2 are heterogeneous with patterned V-S (vowel shift) in dissimilar vowel Sns as specified above .But in striking contrast ,typically D3 speakers have zero vowel shifts with or without similar nasal Sns in current study . However, comparison between groups, within groups, and between individual participants and intra participant progress is practically possible with vowel shift device. The heterogeneity of results in D2 and D1 specifically is a drawback for their overall group comparisons, but each participant has a patterned vowel Sns in vowel shift model listed above in 1-7. VSAPDs of two typical D2 speakers however align to normal target VSAPD like D3 with or without similar Sns, .VSAPD in atypical -D2 speaker has two VSAPD patterns unlike all other participants in this study.

An illustration is considered below to compare VSAPD in D1 to atypical- D2 speaker in the following paragraph. V-S in atypical -D2 speaker(4 and 6 above) is compared with V-S in D1(3rd type above) and other D2 speakers and D3 (1 and 2) for exemplifying purpose(figures 7 and 8) . Vertical synchronic chain shift, Vertical adjacent shift, Vertical drag shift, mergers , creation of new vowel floors in front and central oral articulatory space and newly termed oblique shift patterns are evident in dissimilar Sns of D1 speakers of type 3 (see fig 7 section 1).Except mergers these numerous movements take place in front and central vowels only . Mergers are common to both front and back vowels. These findings when compared with speech bit type 1 in atypical D2 speaker in (see fig 8 section 2) show different VSAPD patterns. In striking contrast to D1 type 3 , absence of mergers, V-S markers of horizontal types, with overall drop - in to back focus, posterior vertical drag shifts in vowels and creation of new posterior vowel floors are seen in speech bit type 1 in atypical -D2 speaker . His speech bit type 2 in contrasts has normal VSAPD unlike in speech both speech bit type1 in atypical –D2 and D1 type 3. Other participants in D2 and D3 like speech bit type 2 have normal VSAPD.

Dual speech bits comprising dual resonances and dual vowel segment behaviors are not reported earlier in hearing impaired literature. Vowel -Shift device in current study differentiated between the two types of his speech bit patterns in conversation task with two VSAPD patterns in atypical- D2 speaker. Absence of similar Sns, normal VSAPD associated with average low pitched voice and fluent speech at conversation is typical of speech bit 2 . Vowel -Shifts are present in other alternating speech bits type 1, comprising similar and dissimilar vowel Sns associated with, tense rigid, relatively minimal jaw movements at speech production, high pitched voice and *Cul De Sac Hyper Nasal Resonance* and word by word intercepted remote sounding speech. Overall, the anterior VSAPD is free from receiving Vowel -Shifts in this D2 speaker. Further both receiving and dispatching V-S are absent in upper high vowel floor in VSAPD of atypical- D2 speaker. Each speech bit type shows strikingly contrastive cluster of speech signs alternating in conversations and narrations of this D2 speaker. A second referral to phono -surgeon has also ruled out any organic involvements leading to this disorder. Neither did his mother recognize these dual patterns in his speech. She says his voice is the same since his childhood, other than low pitch voice changes at his adolescence. VSAPD has successfully differentiated idiosyncratic atypical D-2 speaker from other D2 speakers, D1 and D3 speakers and within his own speech bit types. He has 2 VSAPDs, and unique posterior loci V-S in type1 speech bit contrasting with normal VSAPD in type 2speech bits. These are atypical in current study. The exclusive pocketing of vowels in low back area in VSAPD in D2 is indicative of unique onset of cluster of speech signs with pharyngealization of vowels and nasalizations of vowels at Cul De Sac hyper resonance in recurrences in speech bit type 1 only in this speaker. No organic reasons are identified after a second ENT and phono surgeons' comprehensive examinations. Cluster of speech signs and disappearing alternately is nonconforming to typical nature of hearing impaired speech reports spanning nearly a century. This case with its exclusive patterns of on and off signs of contradictory speech clusters, also leads to speculations of possible synchronic cul de sac hyper nasal associated vowel segmental disorders.

Another overall inference that can be drawn from VSAPD in figure 7, is that with high vowel floors are brought below and also the low central vowels go up to near mid and mid vowel floors there is possible vertical compression of frontal and central phonetic articulatory space at contexts of dissimilar vowel Sns in D1 speakers, . Monsen (1976a, b), Monsen (1983), Monsen & Shaughnessy (1978), had inferred that "reduced phonological space for some deaf speakers does not necessarily mean that the vowels are ill-defined phonemically and that it increases the probability of overlap of vowel targets ". Whether V-Ss are due to vertical compression of vowel articulatory space in D1 (figure 7) is not known. . Shukla (1989) has identified reduced phonological space in Kannada hearing impaired speakers with acoustic investigations. It is however too early to connect these articulatory inferences from current study with instrumental acoustic results. It is recommended, that in future research, these two approaches are integrated and compared.

At the same time, mergers could be speculated as lack of distinction between vowels floors in D1, implicating, possible in discriminate lingual movements across adjacent high, and high mid vowel floors. They are sole vowel shift patterns in posterior VSAPD in D1. Asymmetry in VSAPD is characteristic of both D1 and atypical –D2 speakers. However, the characteristic nature of asymmetry is different in these two types of congenital SNHL as discussed in earlier paragraphs.

AhifsnD1 is an exception in D1 with zero V-S and no similar Sns. ApsnD1 is also an exception for absence of V-S in d1 but with associated similar vowel Sns. They are inferred as type 1 versus type2. An integration of results from preliminary study with body level hearing aid users D0 indicates absence of vowel Sns and hence zero vowel shift in AhifsnD0(Gayathri 2016) .

Thus, at least dissimilar vocalic Sns amongst vowel Sns have inherent patternizations of V-S discovered though VSAPD in accordance with chaos theory of science bearing in random vocalic Sns in realistic conversational corpora of congenital SNHL. The long presumed variability in Sns for nearly a century is partially answered with their underlying systematic patterns exclusive of similar Sns which will be pursued in next series of studies. They help in differentiating different congenital SNHL groups D1, D2 and D3.

Novel VSAPD derivation with markers in this study is a handy device which can be incorporated in all clinical phases not only in congenital SNHL vowels but also in other vowel disorders in speech language pathology. It helps in comparison between groups and intra -individual vowel profiles and in some case in location of hub- spots of vocalic Sns in VSAPD which could be inferred to corresponding oral articulatory space. It can also be derived and applied to all other Indian languages and western languages. It is handy, compact visual device and provides for easy inference which has implications for incorporation into clinical case sheets. It is hypothesized that in organic vowel disorders it may point to hub of their dissimilar vowel Sns which have implications for therapy. Further, multiple samplings of minimal pairs may also project VS in VSAPD. For example, Ramachandra (1999) has illustrated more than 45 vowel minimal pairs of Kannada. These could be adapted, expanded and modified for participant friendly large number of multiple speech samplings to capture vowel Sn variability and assessed on VSPAD with directional markers.

Conclusions

Grounded in the conversational corpora of congenital SNHL are ascertained inherent regularities in some portions of vowel Sns contradicting their long presumed randomness for nearly a century. This is evidenced through similar Sns and dissimilar Sns. Additionally , newly designed VSAPD device with V-S markers is adapted and modified from vowel shift theme drawn from linguistics, depict definite V-S patterns in the three groups of congenital speakers D1, D2 , D3 and an atypical- D2 speakers . This approach has differential clinical applications in diagnoses and therapy. D3 as a group, two D2 speakers, an AspsnD1 , AhifsnD1 have zero vowel shifts. Asymmetry of VSAPD with hub spots of dissimilar Sns can also be identified which has multiple clinical implications in wide range of speech disorders in future. Applications of VSAPD to other languages and speech abnormalities are suggested .Additionally are suggestions for multiple lexical samplings for minimal pairs of a language to design clinical tests and examination of V-Ss on VSAPD .

Limitations

Heterogeneity of D2 group through an atypical speech patterns in a participant in this group demands additional D2 participant inclusions in current study .The VSAPD does not differentiate within similar Sns of duration and NZn substitution vowel error typologies. This approach with conversational corpora for data extraction of vowel Sns is highly time- consuming . Newly designed tests of multiple lexical samplings suggested above may help quick marking of V-S in VSAPD .

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5

Probing Random Diphthongizations in Dyadic Conversation Corpora of Congenital SNHL- Pattern Representations, V

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Abstract

For nearly a century, diphthongizations (DZns) are reported under randomly variable vowel errors in the congenital SNHL speech. These are held as difficult to treat. Random variabilities of DZns in dyadic conversations of congenital SNHL are challenging which itself is probed to explore underlying patterns in three groups of congenital SNHL speakers. Their organized phonetic structures, types of DZns, lexical specificities for their occurrences, phonotactic sensitivities, and overall trends of developmental DZn repairs and hierarchy of patternizations emerged from data analyses. While DZns are typical of analogue BTE hearing aid users (D1) with two exceptions, they are universally absent in cochlear implanted (D3) and in programmable BTE digital hearing aid users (D2). Random DZns in speech corpora, show underlying regularities which bear varied clinical implications in future.

Keywords Diphthongizations, types, mergers, vowels, programmable digital hearing aid analogue BTE hearing aid, cochlear implanted, phonotactics, phonetics, therapy, conversation, corpora

Introduction

Congenital SNHL(figure 1) has severe impacts in speech acquisitions of hearing impaired (Thirumalai & Gayathri1982-1984, 1988).For nearly a century; diphthongization error in vowel articulations is reported in congenital SNHL literature since Numbers (1936) study. There have been numerous technological revolutions in hearing devices for congenital SNHL. Now, the hearing devices in India range from analogue body level hearing aids (D0), analogue behind the ear level hearing aids (D1), programmable digital behind the ear hearing aids (D2) and lastly the surgical cochlear implantations (D3). Virtual differences of diphthongization errors between the dissimilar speech outcomes of congenital SNHL with these separate hearing devices is not known.

In D0 (analogue body level hearing aid users) rehabilitated hearing domain in congenital SNHL, Ling (1976, pp245) had opined that, "Diphthongization may be difficult to ameliorate in the hearing impaired". Markides (1970), Smith (1975), White (1972), Osberger & Mc Garr. (1980), Sfakianaki & Nicolaidis (2016) have also reported DZns in D0 users. In the context of the absence of DZns in sudden hearing loss in a five year old, Binnie, Daniloff & Buckingham (1982) had inferred that, the diphthongization, syllabification, and prolonged duration might be the strategies for enhancing feedback during speech. Zamani, Zarandy, Borghei, Rezai & Moubedshahi (2016) did not find this specific vowel error in Persian speaking D3 users. A Preliminary study on SNHL speech acquisition and articulation reported diphthongization error patterns in adult psn D0 speaker and not in an adult hifsnD0 speaker (Gayathri 2016). In a recent analyses (Gayathri 2019d) with vowel shift device VSAPD , DZns are connected with mergers in Kannada .

Articulation variability of vowel segments is the *SIGNATURE* of speech in congenital SNHL (Gayathri 2019d). An initial examination of vowel defects in previous reports (vowel series II, III, IV: Gayathri 2019) point to prevalent, variable and persistent diphthongization (DZn) errors as Substitution for vowels in congenital SNHL inventories from conversational corpora in long term post therapeutic analogue body level hearing aid users . These errors are relatively conspicuous to a listener at dyadic conversation with congenital SNHL. Study of diphthongs in the speech of congenital SNHL is interesting as these are variable and complex phonetic content replacing simple vowels. Further, these phonetic segments are complex demanding articulatory phenomena of starting from one vowel position and gliding into the other vowel instead of just a simple pure vowel articulations .Unlike consonant clusters, they are relatively slow and successive formations. Why such a complex behavior occurs in this population is an inquisitive question.

This study aims at identifying structural phonetic organization patterns of common but variable residual diphthongizations in conversation data bases of congenital SNHL who had completed long term comprehensive speech and language therapy (LT-CAOSLT) in Kannada with different use of hearing devices. The same are compared between different hearing aid users D1, D2 and D3 hearing domains, which include the behind the ear level hearing aid users, programmable digital behind the ear level hearing aid users and the cochlear implanted respectively. This study is a part of ongoing parent study begun in 2007 on conversational speech of congenital SNHL in different hearing domains D0, D1, D2 and D3. Preliminary report in D0 has highlighted DZn vowel errors in ApsnD1 and not n AhifsnD1 (Gayathri, 2016) .

Methods

The study contains 18 congenital bilateral symmetrical congenital SNHL subjects (table 1) in three hearing domains D1,D2,D3. They had completed intensive long-term oral- aural speech and language therapy (LT-CAOSLT) . Their mother tongue and regional tongue was Kannada. .They also were rehabilitated with any of three different contemporary hearing devices: analogue BTE hearing aids, digital

Figure 1. Affected Parts of Ear in Irreversible Congenital SNHL.

Figure 2: Domain 1, Analogue behind the Ear Hearing Aids

Figure 3: *Domain 2, Programmable Digital, behind the Ear Hearing Aids*

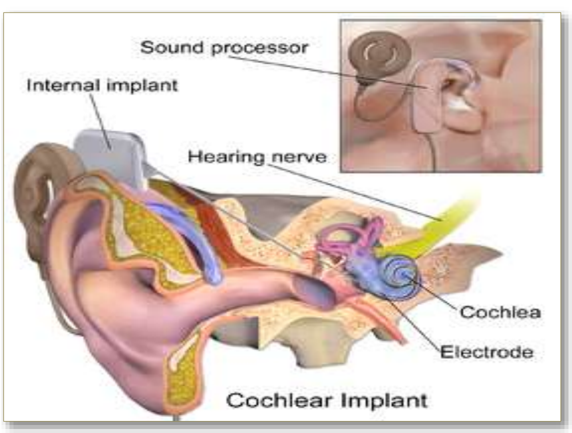

Figure 4: Domain 3, the Cochlear Implanted

behind the ear hearing aids and the cochlear implanted named as D1, D2, D3 hearing domains (figures1, 2, 3, 4) respectively. All participants had completed long term comprehensive aural oral speech and language therapy (LT-CAOSLT) in Kannada and were mainstreamed to normal schools.Table1 provides clinical details of 18 participants in this study.

1. Apsn Domain1
2. Aspsn Domain1 n=2
3. Amssn Domain1
4. Ahifsn Domain1
5. Cpsn Domain1
6. Cmssn Domain1
7. Apsnsib2 Domain1
8. Aspsnsib2 Domain1(**total D1-n=9 , 2 child: C; 2 sibling 2:sib2**)
9. Aspsn D2 Domain2- **n=3**
10. D3 Domain3 - **n=6**

All participants except CpsnD1 and CmssnD1 had completed speech and language therapy
D1= Analogue BTE hearing aid user, both ears n=9
D2=Digital programmable hearing aid user. All were children, both ears, n=3
D3= Cochlear implanted (in one ear), age @sampling – 8-10 years, post speech and language developmental period n=6
Sib2=second congenital SNHL sibling in family, All other participants are the only congenital SNHL in the family
CD1= child, with ongoing speech therapy and language experience for minimum of 7-8 years, parallels with child D3
A=Adult
Criteria of sampling – Completion of long term aural- oral speech and language therapy(LT-CAOSLT), congenital bilateral symmetrical SNHL , mother tongue , regional language Kannada ; Incidental Sampling
Total n=18
(More details in vowels series paper 1,Gayathri 2019, LII jl)

Table1. Clinical details of participants in current study

A conversation section coined as TELS HI /Kannada (Thirumalai and Gayathri 1982, 1988) after its many years of clinical use was administered to the participants in a silent room in face-to-face context. The same was recorded with high quality Sony digital audio recorder with microphone. IPA transcription was adapted with fine attributions where needed. The conversational data comprised of transcribed phons in their uttered lexical units in word ,partial sentences , complete sentences and narrative utterances . Further details of methodology adapted can be seen in Gayathri (Vowel I, in LII jl , 2019). If the conversation had minimal phonetic errors then only those lexicons were transcribed. This situation arose in D2 users and D3 users. Key purpose of this study was to capture defective phons in dyadic conversations within their lexical units

Qualitative perceptual approach was adapted to make judgments of vowel phons and transcriptions.A novel approach to document lexical phonetic transcription was adapted. Word by word transcription was undertaken systematically .In each lexical transcription, flower brackets are used for subject's phonetic segment misarticulation with target phone written in regular brackets adjacent to it. E.g. if [ADalla] is target lexicon, misarticulated phones within this target lexicon was documented as [A{d}(D)a{l}(ll)a].IN [A{d}(D)a{l}(ll)a] those phones in flower brackets are defective : {d}and {ll} . Their target phones are [D] and [ll] are by their side in regular brackets. Overall, they provide for phonetic and phonotactic contexts of the subject's articulated phonetic segment and also the target phonetic segment simultaneously. . By skipping flower brackets participants target word is read, and by skipping regular brackets, misarticulated word is read. By observing, the units within square brackets judgments were done in word context. Thus, the phonetics of target and participant's phon production can be compared in this method of new coding providing space for uttered word contexts

Next step, in current investigation involved qualitative data searching, and extraction of diphthongization errors from the transcribed conversation speech corpora. DZns are defined as phonetically comprising two vowels as substitutions for a monophthong in lexicons. All documented diphthongizations are substitutions to vowels. These were tabulated under a table in their lexical contexts .These diphthongization tokens were then examined under different phonetic lexical dimensions and classified in an organized manner for their pattern identifications. Table 2 show

gaNTeg{ei<}(e)
ta>k{a>i}(i)side
g{u<a>}(a){g}(ng)o{tar}(tr){ie<}(i)
y{ai}(i)lla
{g}(k){uu>o}(o){d}{l}(L)e(i)
{g}(k){uu>o<}(o){d}{l}(L)ei(i)
am{u<oo}(e)le
{a}.{u<o} (e) (-nn)') radu
pii>y{u>o<}(u)se
n{u<o}(o){d}(D)u
g{uo}(o)ti{l<ll}(ll)a
{-}(j)i{ng}(nk){ei<}(e)
g{u<o}(o)tt{ie}(i){l<ll}(ll)a
b{aeae}(e)nk{i~e<}(i)
s{ie<}(i){mp}(mh)A
w{uO}(u)piTTu
gaNT{ei~}(e)

Table 2 Examples of DZn patterns in lexical contexts in D1

representative samples of DZns in their lexical contexts . The tabulated *Diphthongizations set from data bases* are examined for common versus sporadic (<3 in transcribed speech corpora) types. Only frequent types (3+ in transcribed speech corpora) are examined for their phonetic structure descriptions.

Further, their lexical contexts, articulatory dimension distribution patterns, and persistent nature are examined. These findings are listed below.

Results

An overall finding is that the diphthongization error tokens are found as residual vowel errors only in the analogue BTE hearing aid users, D1. In post long term therapeutic digital programmable BTE hearing aid users and in the cochlear implanted (D2 and D3 speakers) they were totally absent in conversational corpora. Listed below are some of the DZn patterns identified in D1 speakers in Kannada.

Findings in D1 speakers

Following paragraphs describe **phonetic nature of** diphthongizations in D1 speakers.

1. **Basic phonetic structures of DZns**.

1.1. **Simple and complex diphthongizations** The DZns comprise of simple and complex diphthongizations Dipthongizations occur as simple two vowel elements y{ai}(i)lla , gaNTeg{ei<}(e); or they are phonetically complex coalesced with duration and nasalization variations am{u<oo}(e)le and nasalization gaNT{ei~}(e) or both b{aeae}(e)nk{i~e<}(i).

1.2. **Sporadic occurrences** of diphthongizations as part of vowel hiatus are also seen, with medial consonant deletion {a}.{u<o} (e) (-nn)') radu .

1.3. **Phonetic elements** identified in DZn tokens are [ei],[ai] , [ie],[uo] ,[ou] ,[ua] . Of these [ai] is native diphthong of Kannada language. Of these [uo] , [ei], [ie] and [ou] are frequently occurring DZns and others are sporadic.

1.4. Types **of common DZns.** [uo] and [ou] are back DZns and [ei] and [ie]are front DZns classified on the bases of their phonetic elements according to phonetic inventory of Kannada (Upadhyaya, 1972).

1.5. **Vowel specificity for DZn occurrences.** The front vowels are substituted by frontal DZns and back vowels are substituted with back DZns .e.g. {-}(j)i{ng}(nk){ei<}(e), g{u<o}(o)tt{ie}(i){l<ll}(ll)a. Hence, they are specific to their target corresponding to front or back vowels.

1.6. **Rising or falling DZns** .Of these, most common DZns [ei] and [uo] are indicative of presence of both rising and falling type of DZns in conversations.

1.7. **Vertical mergers** An application of vowel shift approach to DZns in previous study with these same set of subjects as, has identified (Gayathri ,vowel series IV 2019d,LII jl) that frequent diphthongizations exhibit vertical mergers of adjacent vowel floors in front and back of oral articulatory space leading to diphthong formations [ie], [ei] ,[uo] and [ou] .

1.8. **Distribution of DZns in Kannada phonetic inventory** Another previous study has identified that common and less common diphthongizations occur only with front and back vowels of Kannada inventory (Gayathri 2019, vowel series II, III, IV, LII jl) and not on target low central vowels. On a similar count, it was found that they occur with target high and high mid vowels. Vowels (Gayathri 2019, Vowel series III, IV Gayathri 2019 LII jl) .

1.9. **Articulatory dimension of** lip **roundedness** Unrounded front DZns are substituted for unrounded front vowels and rounded DZns are substituted for rounded vowels as a corollary to 1.5. .

1.10. **Variability** Common are variable in the sense that the same DZns may reappear in successive conversations in different manner of phonetic organizations. The elements of DZns are varied either in duration or in nasalizations. Alternatively, the target vowels are normally articulated or are subjected to other vowel errors.

1.11. **Alien Diphthongs to Kannada**. The common DZns [ei][ie][uo][ou] are alien to Kannada language .

1.12. **Common DZns comprise** either solely front double vowels or solely back double vowels. No central vowels exist in common DZns.

2. Analyses of common **DZn occurrences in D1 speakers in their lexical contexts.**

The DZns are substitutions to target vowels in a word.. These are named as explicit DZns in previous study (Vowel series II Gayathri 2019, LII jl).They show following regularities with insignificant exceptions

2.1 They generally occur in initial, medial and final positions in word utterances. This means that vowels in all word positions are vulnerable to diphthongizations.

2.2.. Sometimes , same lexicons comprise more than one diphthongizations g{u<o}(o)tt{ie}(i){l<ll}(ll)a .

2.3. More often diphthongizations [ei] and [ie] are observed in word final contexts. {-}(j)i{ng}(nk){ei<}(e). But, [ou] and uo are found in word medial lexical contexts e.g. g{u<o}(o)tt{ie}(i){l<ll}(ll)a, w{uO}(u)piTTu. There also exist rare exceptions to this pattern.

2.4. No additional definite phonotactic constraints were identified for frontal diphthongizations.[ie] and [ei] However, some additional patterns are identified for medial lexical posterior -diphthongizations [uo] and [ou] .

3. **Phonotactic sensitivities for Posterior DZns [uo] and [ou] in D1**.

An in-depth examination of [uo], [ou] in lexical contexts DZns unlike in [ei] and [ie] yields their advanced patterns in the conversational speech corpora.

3.1. **Word Medial posterior or back DZns in adjacent anterior coronal consonant contexts in uttered lexicons.** e.g. in contexts of dental consonants [t],in g{uo}(o){t}(tt) i{L<ll}(ll)a. In this example, dental geminate cluster is articulated by corresponding dental consonant is adjacent to back vowel[o] .Thus, is derived the rule: **-VC-** where V= Back rounded vowels and C= anterior coronal consonant. But, sporadic exceptions to this are also are seen in some participants only .e.g. in subject CmssnlD1 [u] + [labial +post back vowel] > w**{u<o}(u)p**iTTu and in Aspsnsib2D1 w{**uO}(u)p**iTTu , w**{u<o}(u)p**iTTu .

3.2. **Medial back DZns occur in lexicons with medial posterior vowel+ adjacent HMO cluster** *contexts.* Evidence for co articulation effects in these anterior coronal contexts can be seen in examples in table 1. e.g. d{u<O}(o){ND}(DD)a, tek{u<O}(o)NDu , tek{u<o}(o)NDu;**-VCnCo-.**

3 .3. **Medial back DZn occur in lexicons with medial back vowel+ adjacent anterior coronal geminate contexts** *–eg:* (g){u<o}(o)ttilla ; **–VCC-**.

3.4. **Medial Occurrences of back DZn in with medial posterior vowel+adjacent heterorganic clusters context with anterior coronal consonant component adjacent to back vowels**. Word medial heterorganic__clusters with its initial anterior coronal element leads to DZns .Examples t{Uo<}(o)LE{dt<}(d)(u-),k{u<o}(o)DbEkA{r}(dr)e**;. –VCC1**-.

3.5. The rules 3.1 to 3.4 also apply to to defective **substituted anterior coronal consonant** in the uttered lexicons in conversational corpora . E.g.in m{u<O}(o){L<l}(l)a {L<l} is substituted coronal articulatory transient for anterior coronal consonant (l).DZns occur in this misarticulated consonant context .context. Similar observations can be found in e.g. P{u<O}(o)T(TN)a , p{u<O}(o)T(TN)a:T/TN.

3.6. **Prevocalic to medial DZns are not rule governed.** Rules for prevocalic is not found for formation of [uo] [ou] DZn patterns e.g. **{w}(**d){u<O">}(O){n}(N)I, **{t<d}(**d){u<O}(O){n}(N)I, **g{**u<O>}(O){t}(tt)i{l}(ll)a.

3.7 **Manner of articulations of anterior coronal consonants was not a significant variable** in clauses 3 to 3.5. DZns [uo] and [ou] occurred with anterior coronal stops, fricatives, laterals, flaps and nasals. . The segments could comprise of single anterior coronal consonants and their clusters in D1.

3.8. When medial back vowels in lexicon are followed by bilabial consonants or velar consonants, DZns are not formed in D1 .

3.9. **Back Dzns are rule governed with its phonotactic constraints** From the above clauses, it is therefore clear that occurrences of common back DZns are rule governed with its phonotactic constraints . When posterior DZns occurs in D1, they either are the impacts of articulatory interactions of articulation of medial posterior vowels with their post vocalic anterior coronal phonetic segments of the target form or substituted forms in lexicons. The results from 3 to 3.7 presented above apply only for back rounded [uo] and [ou] DZn error formations in congenital SNHLD1 speakers. Where V= back vowel [u]or [o]; V1V2= [uo] or[ou] (imply back DZns) ,C= either anterior normal or substituted of coronal consonant, or corresponding clusters of geminate ,HMO cluster and HTO cluster types with its first element being anterior coronal consonant . Phonotactic conditions for back DZns are illustrated in table 4. These contexts trigger back DZns in D1 speakers:

1) -vc- = medial back/posterior vowel, anterior coronal consonant > -v->-v1v2-
2) -vcc- =medial back/posterior vowel, anterior coronal geminate >-v-> -v1v2-
3) -vcnco- = medial back/posterior vowel cnco =anterior coronal homorganic cluster (HMO) with nasal oral consonants -v- > -v1v2-
4) -vcc1- = medial back/posterior vowel, cc1= HTO cluster =c=anterior coronal consonant, c1=second consonant, -v-> -v1v2-

Table 3 .Phonotactic rules for occurrences of back DZns in lexicons in D1

The clauses from 3 to 3.9 and the subsequently derived phonotactic rules 1,2,3,4 (table 3) for their occurrences , are suggestive of co- articulatory impacts to the occurrences of posterior back DZns [uo]and[ou] in conversation contexts illustrated in 3.8. These newly identified rules for DZn have remained obscure and untouched in the vowel literature of congenital SNHL under "**the broad blanket wrap of phenomenon of variability of vowel artciulatory errors, presumed to be due to lack of sufficient and efficient auditory feed back at speech acquisition and at monitoring in speech production , since 1936** " .

In addition to above rules, the following are not the variables for occurrences of medial back DZn occurrences in lexicons.

1. Manner of articulation of post -back-vocalic anterior articulatory consonant under 1,2,4 is not a variable .
2. Pre vocalic consonants in –vc- are not a variable for DZn formations.

3.10. At a few DZn tokens in AspnsD1 ,CmssnD1 , and AmssnD1 for example, forward lower jaw movements at DZn occurrences were conspicuous eg: at articulation of [mousranna] for [mosranna] in AmssnD1

4. Developmental repairs of DZns in congenital SNHLD1. While DZns [ei] and [ie] repair and disappear with better language experiences in participants such as in AspsnD1 , AmssnD1 , DZns [uo] and [ou] remain persistent . For example in Aspsnno2 who is a fluent speaker, with several narrations in her conversations has no [ie] and [ei] DZns .But, she has back DZns [uo] and [ou] . However, ApsnD1 who spoke in word after word manner in partial and simple phrases and partial and complete sentences and Similarly , CmssnD1 and Aspsnsib2D1 has both front and back DZns In striking contrast, AmssnD1 who has better language than CmssnD1 has only few back DZns .

5. **Persistent posterior DZns** .The persistent and last residues of posterior DZns are more often associated with retroflex consonants and clusters with back vowels. For example , in Aspsnno2D1, has only several retroflex consonant and their cluster associated persistent back DZns at vowel articulation[o] .This has implications to Dravidian and Indo Aryan languages of India with prevalent retroflex consonant and their cluster contents in their inventories.

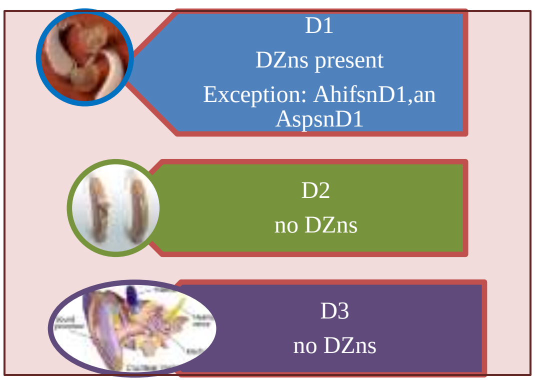

Figure 5. Occurrences of DZns in D1, D2, D3 Kannada congenital SNHL speakers

6. A significant finding is that DZn vowel errors are universally absent in residual vowel errors of both D2 and D3 speakers and in AhifsnD1, and an AspsnD1.

Discussion

The purpose of current study was to explore regularities that might exist in DZn that are the substitutions for vowels in a lexicon . Conversational speech of three hearing domains, D1, D2 and D3 of congenital SNHL are explored. All participants have undergone long term comprehensive aural oral speech and language therapy (LT-CAOSLT) and mainstreamed to normal schools or vocation. DZns are variables like all other vowel errors. Variability of vowel segments is the *SIGNATURE* of speech in congenital SNHL reported since year 1936 (Numbers). A preliminary study had revealed variable, prevalent, persistent DZns in both AspsnD1 and ApsnD0 (Gayathri 2019 vowels series II ,LII jl ; Gayathri 2016) .They also present surface variability in conversational speech corpora of the D1 users (Gayathri 2019a, c, d, e vowels series I, II, III, IV in LII jl). They are attributed to and wrapped *under the traditional presumptions of degraded efficient auditory feedback at speech production and hence, the vowel misartciulation* variability. Thus, the bulk of DZns which is also vowel defect is remaining neglected in congenital SNHL. Contradictory evidences to the conventional presumptions, portraying array of organized patterns for common DZns are outcomes of present study. From speech corpora in current study, variability is however first evident. A vowel need not always be DZd in conversation data . But , it shows possibilities of outcomes of normal articulation, omissions and substitution errors distributed in the conversation speech corpus in congenital SNHLD1 .But, analyses of the DZn errors in this study demonstrate, types of DZns , several phonetic specificities and phonotactic rules for one type of DZn . These findings partially refuting the long presumed concepts on overall variability of vowel defect is discussed in the following paragraphs.

Firstly, the DZns are explicit to rehabilitated hearing domain types and type of hearing loss .The DZns are absent in D2 and D3 speakers, but in contrast, are present only in D1 speakers except in AhifsnD1 and in an AspsnD1 (figure 5) . Thus ,It can be concluded that **DZns are markers of D1 speech** .If data from preliminary study (Gayathri, 2016) is cumulatively integrated, the DZns are also evident in the D0 psn speaker, which is the hearing domain of analogue body level hearing aid . It is possible then that DZns are *speech markers* of analogue hearing aid users in at least psn D1 and D0, in AspsnD1 , in adult and child mssnD1. Poor auditory feedback at speech production, in analogue hearing aid users (D1 and D0) compared to advanced technologies of D2 and D3 could then be the cause for DZNs. This again is conforming to the conventional presumptions above. Under conditions of poor auditory feedback the congenital SNHL rely on oro -sensory motor feedback. Some investigators have speculated that lack of auditory feedback leads to slow speech production and consequent DZn in SNHL (Ling 1976). Yet , analyses in current study reveals that they do not manifest randomness but organized linguistic patterns . It is not known if they occur at all inD2 and D3 in their developmental speech acquisition phases.

Not only D2 and D3, but also AhifD1 and AhifD0, of analogue hearing aid user types from similar preliminary study (Gayathri 2016), with access to low frequency hearing have no DZns. A contradictory finding is seen in only one AspsnD1 who has shown zero dissimilar vowel error substitutions in previous study (Gayathri 2019, e). This then also includes zero DZns in this subject .But, in contrast to this; two other AspsnD1 speakers with similar hearing loss show DZn occurrences in their speech corpora. But, on the other hand, under D2 hearing domain, three Aspsn also show absent DZns. The last finding of zero DZns in D2 relative to D1 with similar sp -SNHL can be clearly connected to better auditory feed back at speech acquisitions and speech production in the Aspsn in D2 group. Similar arguments good low frequency auditory accessibility for absence of DZns is held for Ahifsn under D1 and D0. But, in spite of relatively poor auditory access in D1 and D0, yet the DZns show organized patterns phonetically and to some extent phonotactically which have clinical inferences . Back DZns have relatively added regularities than front DZns.

Since the aim of this study was to identify patternizations of variable DZn errors, only common DZns with exclusion of sporadic DZns in D1 were considered for analyses. DZn [ei, ie, ou] and [uo] in D1. Their structural phonetic organization patterns were first examined .These patterns are listed in 1 to 1.10 above. These can be considered as beginning emergence of patterns in DZns of D1 .

The DZns also demonstrate few phonotactic specificities. Specificity to their lexical positions is identified for both front and back DZns. While [uo, ou] occur in lexical medial positions, [ei , ie] occur in lexical final positions in general, with sporadic exceptions . Additional probes point to possible co-articulatory impacts of DZns [ou] and [uo] DZn s in contexts of articulation of medial [u] or [o] as pre vocalics to anterior coronal consonant contexts (3 to 3.9,fig 6, table 3) . These medial post vocalic anterior coronal consonants encompass a range of coronal consonant contexts .These comprise , their single consonant types ,geminate clusters , homorganic clusters ,heterorganic clusters .This rule is found generalized to anterior coronal consonants of all manners of all articulation . In contrast, the back DZns are absent in the context medial post vocalic (+ back), labial and velar consonant contexts . Therefore, back DZns show definite specificity and sensitivity in phonotactic contexts for their occurrences. No such properties are discovered for [ei] and [ie]. Thus with the discussion from above paragraphs , it is concluded that DZns are not a random variability .But they have organized patterns in few linguistic dimensions. Even though , they are present in only D1 or D0 domains with in efficient and insufficient auditory feedback (relative to D2 and D3) in general , their bulk of randomness in conversational speech corpora can be broken and stratified to several regularities. A further study of literature of speech in D2 and D3, indicates absence of any mention of term DZn in overall vowel studies in general

Certain developmental issues to DZns in congenital SNHLD1 are also identified .While [ei] and [ie] repair in persons with better language experiences e.g. Amssn D1 versus CmssnD1. Persistency of

[uo] and [ou] is a critical issue of DZn. In addition, postvocalic (+ back) medial retroflex contexts are the last to repair amongst anterior coronal contexts evidenced in AspsnD1. This has implications for their differentiated occurrences in India which is a multilingual country. Bhaskar Rao (2011) mentions of presence of Retroflex sounds in all the Dravidian languages, Indo-Aryan languages (except Assamese), in some Tibeto-Burman languages, Austro-Asiatic languages . Thus in former Indian language groups long persistence of DZn error is predicted compared to latter language groups . Further the DZn errors prevalent at least in profound SNHL in D1 and D0 and child mssnD1 in Kannada .This is in striking contrast to Markide's (1983) findings, who had found least prevalent DZns in their English speaking deaf subjects. He also mentions of least prevalent DZns in partially hearing subjects. This is in agreement with current study when AmssnD1 is considered.

The patternizations of DZns open the streamlining of assessment, derivation of clinical tests loaded with medial back vowels with adjacent anterior coronal consonants, and high front vowels in word final positions for clinical assessments and speech therapy for common DZn errors . At this juncture, Ling's (1976) contention that the diphthongizations are difficult to ameliorate is also refuted. Previous studies had also pointed to specificity of DZns vowel errors only to high and high-mid – front vowels (Gayathri, 2019, c, d,e LII jl).They are also pointed as phenomenon of *mergers* in VSAPD approach (Gayathri ,2019,d) . Their consistency to the factor of corresponding lip roundness articulatory dimension is also to be recognized.

Therefore, unlike traditional presumptions and acceptance of 'randomness' of vowel errors mentioned earlier, at least common DZns are rule governed .The front and back DZns show different lexical position specificities More specifically, the [uo ,ou] have definite phonotactic specificities and sensitivities in Kannada . Thus, it can be stated that performances of frequent front and back DZns have asymmetrical behaviors in congenital SNHLD1. In spite of their variable occurrences, underlying organized phonetic nature and phonotactic specificities leading to the speculations of co articulatory parameter for occurrences of back DZns in D1 is unraveled in this study. Clause 3.10. mentions a few DZn tokens in AspnsD1 ,CmssnD1 , and AmssnD1 for example, forward lower jaw movements at DZn occurrences were conspicuous eg: at articluation of [mousranna] for [mosranna] in AmssnD1 . Objective studies on lingual movements at DZn errors in D1 or D0 in lexical contexts with multiple samplings in future may help understand this articulatory phenomenon. Why this impact of co articulation occurs for [uo and ou] in D1 and psn D0 only is not known. It is also evident that with better auditory access in D2 and D3 DZns disappear. Lastly, findings of DZn patternizations in current study in D1 can also be hierarchically organized as seen in fig 6.

Even though, most D1 speakers had completed LT-CAOSLT, persistence of DZns as substitutions of vowels in conversation of D1 speakers lead to imbalance in the overall proportions of vowel, consonants and diphthongs .in Kannada (Ranganatha1982) . The frequency of occurrence of diphthongs in Kannada is low. The frequency of occurrence of native diphthongs [ai] and [au] are 1240.23(0.02%) and 365 0.70(0.06%) respectively in one lakh words with 54, 41,650 phonetic segments. From this study abnormally greater proportions of Diphthongs are predicted in speech of congenital SNHLD1 and D0 in Kannada. This probably typifies speech of congenital SNHL in D1 and D0 speakers.

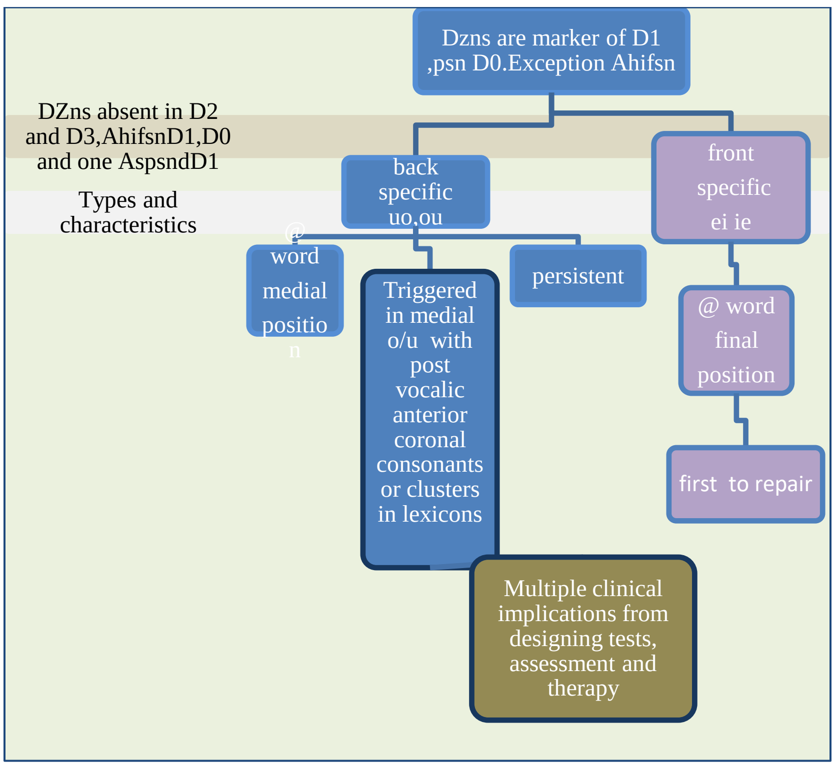

Figure 6 .Hierarchical organizations of regularities of DZns in D1

Further, some of these adult D1 participants and psn D0 with this obviously perceivable defective speech encompassing DZns are vocationally community integrated after the LT-CAOSLT. These could reflect on the D1 persons in day to day life. But, with these novel discovery of rule governed DZns should help in overcoming DZns at speech and language therapy wherever D1 and D0 are in use exclusive of AhifsnD1, D0, for better outcomes in their oral speech articulations.

Caution should also be taken while young children are waiting for implantation of D3 device. With the findings from current study, it is suggested that, it is ideal to fit the child with better hearing devices such as D2 until the D3 intervention is undertaken. This is important to forego the circuitous cycle of cognitive learning and unlearning of two different types of speech, with and without diphthongization errors in the crucial sensitive critical period of speech and language acquisitions.

Conclusions

DZns are typical markers of speech of analogue hearing aid users, whose proportion of diphthongs ratios are predicted to be in imbalance with vowel and consonants compared to these proportions in Kannada . Exceptions to this finding in D1 and D0 analogue users are the Ahif SNHL participants. The DZns are universally absent in D2 and D3 speakers. The participants types who showed zero residual Dzns throughout their conversational corpora illustrated in figure is depicted in figure7, having

Figure 7. Zero DZns spans in contemporary congenital SNHL participants after the LT-CAOSLT

cumulatively integrated results from preliminary study with D0 speakers (Gayathri, 2016).

There occurs organized phonetic patterns and phonotactic specificities and sensitivities, for the occurrences of common residual DZs in conversational corpora of D1.Certain phonotactic contexts trigger back DZns implicating co articulatory outcome to occurrences of back DZns. They have remained as neglected bulk of vowel error in congenital SNHL for nearly a century under the *blanket term variability of vowels due to deficient auditory feedback*. With these novel findings, assessment and systematic therapeutic approach to curtail residual DZns should be possible. Precaution to withhold D1 or D0 hearing aids while cochlear implantation is awaited is discussed .Instead a stand by D2 hearing aid can be used from a repository at this juncture.

While, the arguments of degraded auditory feedback for vowel variability cannot be totally refuted, due to evidences of their presence in D1 and D0 versus D2 and D3, one fraction of vowel variability, the DZns, are organized on several linguistic parameters, which help to overcome them at therapy in future. Phonotactic rules specially govern the persistent back DZns which therefore can be attacked in speech therapy. Why the co articulatory back DZns occur in D1 and D0 but not in D2 and D3 cannot be scientifically reasoned at this juncture .

Limitations

This study focused on only common DZns for need of large tokens for their systematic patternizations. Second limitation is that at incidental sampling in current study no congenital Ahifsn in D2 was encountered. Hence, there is a lack of Ahifsn participant in D2 group.

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6

Triphthongizations as Vowel Substitutions in Kannada, a Misarticulation not Reported in Speech of Congenital SNHL VI

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Abstract

Data driven exploration vowels in dyadic conversation corpora of congenital SNHL in a parent study for in depth study on nature of vowels, led to discovery of novel TZns (triphthongizations) in congenital SNHL .They are explored further in various types of hearing device users. Further, phonetic pattern identification of TZn and phonetic constraints in lexical contexts under which they occur is also investigated. While it appears that, the fluent speaker has TZn and not the severely hearing impaired psnD1 with relatively limited language show evidences of its presence, it is justified that the former AspsnD1 with more advanced phase of speech acquisition encounters the specific lexical constraints under which the TZns arise. Back TZns arise in medial high mid back vowel [o, O] in adjacent post vocalic retroflex consonant and their clusters lexical contexts. Further, D2 and D3 speakers in general show no DZn in contrast to D1. Those who have TZns in the D1 rehabilitated hearing domain also have DZns in their speech corpora .The definite environment under which TZns occur and their consistent phonetic nature indicate co articulatory nature of TZn , and prognosticates remedy through speech therapeutic approaches.

Keywords triphthongization, vowel substitutions, phonetics, phonetic constraints, retroflex, cluster, articulation, jaw, lips, lexicon , deaf , hearing impaired ,speech corpora , conversation , pattern identification , variability , congenital SNHL , analogue behind the ear level, cochlear implanted , programmable digital , hearing aids, exo labial, coarticulation, phonotactic

Introduction

Irreversible bilateral congenital SNHL at birth (fig 1) has serious impacts on first language speech and language development. Intensive long term comprehensive speech and language therapy is part of rehabilitation after hearing aid recommendation in these children (LT-CAOSLT). Reports on articulation of speech in SNHL have spanned since 1936 with alongside technological revolution and developments of hearing devices upto modern day binaural multichannel cochlear implantations. Vowel disorders in SNHL are vastly reported in SNHL with continuing acoustic research of vowels in the cochlear implanted. Substitution errors in vowels are common articulation errors reported in SNHL. Diphthongization (DZn) of vowels is amongst one of these vowel defects reported by various investigators (Numbers 1936, Markides 1970, Ling 1976, Levitt, Smith & Stromberg 1976, Ramadevi 2006; Gayathri 2016, Gayathri 2019).

Figure 1. Affected parts of the ear in irreversible congenital SNHL

While, Hudgins& Numbers (1942) found 50% DZn errors, Levitt, Smith and Stromberg (1976) have found only 1% incidence of DZn. But, none of the studies has reported occurrences of triphthongizations (TZns) in SNHL subjects. A previous data driven study on vowels in conversation speech corpora of congenital SNHL study has identified novel triphthongizations(TZn) as a vowel error (Gayathri 2019, LII submission ,vowels II) in Kannada language in congenital SNHL speakers . This was a noted finding in D1 speakers (analogue behind the ear level hearing aid users) , unlike D3 (multichannel cochlear implanted) and D2 (programmable digital behind the ear hearing aid users) speakers . This study focuses on phonetic pattern identification of these TZn defects in the congenital SNHL in Kannada the results of which is presented in this short report .Its focus is also on phonetic constraints under which the more common TZns occur in lexical contexts at dyadic conversations .

Methods

Congenital SNHL participants involved in study(table 1) ,data collection and transcription of conversation speech corpora involved the same methods of parent study initiated in 2007 as in previous papers (Gayathri 2019, vowel series: I to V, submission to LII Table1.). A total of 18 participants were involved in conversational task 12.3, of TELS/HI – Kannada (Thriumalai and Gayathri 1982, 1988) .Their conversations were audio recorded and transcribed. These are explored for presence or absence of TZns and for identification of phonetic patterns.

Table 1 .Clinical details of D1, D2, D3 participants in this study, n=18

1. Apsn_Domain1
2. Aspsn_Domain1 n=2
3. Amssn_Domain1
4. Ahifsn_Domain1
5. Cpsn_Domain1
6. Cmssn_Domain1
7. Apsnsib2 Domain1
8. Aspsnsib2 Domain1
9. Aspsn D2 Domain- n=3
10. D3 Domain - n=6

All participants except CpsnD1 and CmssnD1 had completed speech and language therapy
D1= Analogue BTE hearing aid user, both ears, n=9
D2=Digital programmable hearing aid user. All were children, both ears
D3= Multichannel Cochlear implanted (in one ear/UL), age @sampling, age: 8-10 years, post speech and language developmental period
Sib2=second congenital SNHL sibling in family
C, D1= child, ongoing speech therapy, and language experience for 7 years, parallels with child D3
A=Adult
Clinical User friendly acronyms for degree and type of SNHL e.g. psn=profound SNHL, hifsn=high frequency SNHL, mssn=moderate severe SNHL
Criteria of sampling – Completion of long term comprehensive aural- oral speech and language therapy (LT-CAOSLT), congenital bilateral symmetrical SNHL, main streaming to normal schools; Incidental Sampling
Total n=18

Definition of TZn. TZn as vowel substitution is also termed as explicit TZn (Gayathri 2019, vowel series II, submission to LII) .There occurs in place of pure vowel a substitution by three vowel element phonetic segment in a lexicon. TZns may or may not coalesce with durational and nasalization changes. In addition, Triphthongs do not exist in Kannada language.

Table 2 Examples of word lists with TZns listed under respective hearing domains		
CmssnD1	AspsnD1	One AspsnD2
yId{aei<}(e) 4	t{uOƆ}(O){L}(r)isbeDA d{u<O>Ɔ}(o){ND}(DD)a t{Uo>Ɔ>}(O){L}(r)isbeDA t{uOƆ }(O){L}(r)isbeDA n{u<oƆ}(O)Dbaarduu k{uo<Ɔ}(O)TbiuTTu m{u<oƆ}(o)DvE b{U>o<Ɔ}(O){Dm}(rD)mEle k{uo>Ɔ}(o)Laa *k{**uo<Ɔ}(O**)TbiuTTu* t{e}(a)g{u<O}(o){D}(ND){I}(i)((dIni-)	k{u<o<Ɔ<}(o)DbEk{A~}(A)dr{e~}(e)
[-aei<]/ [-e] Sporadic, 4 samples confined to one lexicon only	[-uoƆ-]/[-o-] with duration coalesces	Only a single lexical sample in his inventory

All congenital SNHL participants with different hearing devices D1, D2 and D3 (Table 1) in this study had completed long term comprehensive oral aural speech and language therapy (LT-CAOSLT). Participants who showed residual triphthongizations in speech corpora were listed. Data searching for lexicons with triphthongization vowel defects were sorted and tabulated. Examples of lexicons with TZn can be seen in table 2. The phonetic nature of TZns in lexical contexts is analyzed and described in following section.

Results

Much idiosyncratic regularity is identified for TZns in terms of their phonetic nature, vowel substitution nature, lexical positions and lexical contexts as described below. Common aspect of target vowels in these idiosyncrasies is that the high mid vowels of Kannada are affected with TZns

1. **Participants who showed triphthongizations** in speech corpora are child moderate severe SNHLD1 (CmssnD1) and with seven years of language experience with LT – CAOSLT. In addition, it was observed in an adult severe profound SNHLD1 (AspsnD1) after the

completion of LT – CAOSLT. This was absent in D2 and D3 speakers in general . They are also absent on AmssnD1, in AhifsnD1 and other AspsnD1sib2, ApsnD1 participants.

1.1 One CmssnD1 and one AspsnD1 participant who exhibited TZns also have DZns in their conversations.

1.2 AspsnD1sib 2, ApsnD1, AmssnD1 have DZns from many to sporadic nature but they do not have TZns in their speech corpus.

1.3. An AspsnD2 speaker also showed only one evidence of TZn n his fluent speech corpus k{u<o<Ɔ<}(o)DbEk{A~}(A)dr{e~}(e), Hence no analyses is made on this rare TZn sample in single lexicon .

2. **Phonetic nature of TZns** in CmssnD1 vowel elements in TZn contained [aei] and in AspsnD1 the TZns contained [uoƆ]. The latter type f TZn is also seen in one lexicon only in D2. Thus, nature of TZns is specific to participants in D1 speakers.

3. **Vowel on which TZn substitutions occur** are also consistent [aei] /[-e] and [uoƆ]/ [-o,O-] like DZns in previous study , Front TZns occur in front vowels[e] only and back TZns occur for back vowels [o,O] only.

4. **Lexical position of TZn occurrences** Front TZns are found in uttered word final positions only and back TZns occur in uttered word medial position only.

5. **Degree of occurrence of TZns.** In CmssnD1 [aei] / [-e] occurrences are <5 in her speech corpus termed as sporadic in this study. In addition, it is seen in same target word *ide*. In AspsnD1 TZns are found in medial position only for different target lexicons (see table2).

6. **Susceptibility of TZn defect types** to NZn defects in [-aei] / [-e] type occurrences are completely absent. However, susceptibility to length variations of phonetic elements are seen in [-uoƆ-]/ [-o-] type occurrences.

7. **Phonotactic constraints.** No definite phonotactic constraints can be inferred for CmssnD1 with sporadic TZns with same target word being affected in all 4 incidences. But, in AspsnD1 TZns are found in medial position only when followed by retroflex consonants or retroflex clusters (table2).

8. **Comparison of other articulatory errors on target vowels in uttered lexicons in conversation corpora**. Target vowel [e] is compared with other target vowels [e] in her speech corpus in CmssnD1. Similarly, observations are made for target vowels [o, O] in AspsnD1.

8.1.1. **Accuracy** in vowel articulation of [e] in *yide, y{I>}(i)d**e**, yidd{A>.**e}** (-r)'),* idA *ba{dd}(nd)**e**, m{a~}(a){ngg}(neg)**e,** m{a~}(a){ngg}(neg)**e ,** AmE{n}(l)**e** , {A+}y{I}(i){dd}(d)**e** {k}(h){ae>}(E)g**e,** a{L*}Ed**e.***

8.1. 2.Alternate vowel substitution on vowel [e] are by [a],[A], [i],[ae] and [O}in *b{a}(A){d}(L)**{ae} (e)**, y{**i}(e)**l ((li-),{A+}yi{dd}(d){**a}(e),** man**{i}(e).***

8.1.3. Long vowel (duration) substitution for short vowel [e] in *k **{e>} (e)** {li>s} (ls) **a.*** A D2 sample of TZn was short in duration compared to those in D1 speakers.

8.1.4. Her speech contained **DZns** such as [ie][ei] *g{A>}(A)y{A}(a){tAr}(tr){ie<}(i),* m{a~}(a)n{E~i}(e), *{ g}(k){uu>o}(O){D}(L){ei<}(i), (-n))A{r>} (r) {ie<} (i) and uo and ou DZns* w{u<o}(u)piTTu, *{g}(k){uu>o<}(O){D}(L) ei(i),m{ou}(U)ru.*

8.2. AspsnD1 with TZn has following vowel patterns of target vowel [o] or [O]. Unlike CmssnD1, AspsnD1 is fluent speaker with 17 ½ years of language experience in D1 hearing domain. Her conversation corpus thus contained larger speech sampling and advanced lexical complexities than CmssnD1 *AspsnD1 shows either accuracy of vowel articulation, or DZns with a sporadic e/o in k{e}(o)tamari.*

8.2.1. **Accuracy in vowel articulation of target vowels [o,O]** in *mAD**O**{b}(kb){a.u}(-r)')tE, k**O**{l}(L)A , biD**O**{n}(N)a n**O**{n}(D)**O**Na n**O**{n}(D)**O**Na, {m}(b)i{n}(D)**O**Na, {m}(b)i{n}(D)**O**Na taek**o**{nn}(ND)U, m{**a.O**}(-D)')du , sA{t}(nt)**O**{s}(S)a ,w**o**{b}(bb)A>, w**O**{g*}(g)abEDa, g**o**tAga{ll<}(ll)a, n{**O.i}(-**D)')dya ? Ak**O**((NDU-), n{**O.i**}(-D)')tu, ma{t}(rt)**O**gide , s**o**{pp<}(pp)u, r**o**{TT<}(TT)i, mA{db}(Db)iD**o**{b}(kb){a.u}(-r)')te, hA{k^<}(kk)**O**(-NDi)'){d}(dd)Ini, hA{k<}(kk)**O**(NDi)'){dd<}(dd)Ini , k**o**{n}(+)bba{n}(r)I , k**o**bba{n}(r)i , g**o**{t}(tt)I{n}(ll)apa, w**o**{TT<}(TT)e* **,** **o**{bb<}(bb)a. Accuracy of vowel articulation with post[o] bilabial , alveolar , retroflex, dental, velar consonant ; lateral ,stops, nasal, fricatives , and also anterior coronal consonant or their clusters geminates., HMO-NO , V-V hiatus at medial Cn deletion is observed in her lexical contexts extracted from her conversation corpus . Articulation accuracy of these back high mid vowels is also noted in word initial lexical contexts .It is evident that speech corpus contains competent vowel articulation in medial vowel [o,O] followed by retroflex consonants also as in *biD**O**{n}(N)a, n**O**{n}(D)**O**Na, n**O**{n}(D)**O**Na, {m}(b)i{n}(D)**O**Na, {m}(b)i{n}(D)**O**Na, hA{kk<}(kk)O>{D}(ND)u, wOD{E}(e)de , do{DD<}(DD)ama , mo{TT<}(TT)e , wo{TT<}(TT)e , ro{TT<}(TT)i, doNN{a}(e)* contradicting 7 above .

8.2. 2.Alternate vowel substitution on vowel [o] is in one lexicon only *k{**e}(o)**tamari* .

8.2.3. Her speech contained **DZns** such as [uo]and [ou] *types: g**{u<o}(o)**lAbi , w**{ou<}(O**)daytu, k**{u<o}(o)**DbEkA{r}(dr)e , k**{u<o}(o)**DbEkA{r}(dr)e, k**{u<O}(u**)DiwA , d**{u<O}(o){**ND}(DD)a tek**{u<O}(o)**NDu,tek{u<o}(o)NDu, t{**uO}(O**){L}(r)isbeDA t{e}(a)g{**u<O}(o**){D}(ND){<I}(i)(-)((dIni) , t{e}(a)g**{u<O}(o**){D}(ND){<I}(i)(-)((dIni), g**{u<o}(u**)lAbi, k**{uo}(u**)DIbEDi , t**{uO}(O){**L}(r)isbeDA k{**u<o**}(o)DbEkA{r}(dr)e ,k{**uo**}(o)DbEkA{r}(dr)e , k**{u<o>}(**o)DbEkA{r}(dr)e. She also has absence of frontal DZns [ei] and [ie] types in her speech. (See Gayathri 2019, Vowel series V, LII submission).* She has overcome other anterior coronal induced DZns in her conversations with remnants of only retroflex segments induced back DZns only.

8.2.4. Thus, word medial [o,O] + retroflex segment >TZn/DZn/normal vowel articulation in AspsnD1 .

9. Articulatory observation at TZn.

9.1. [-uoƆ-]TZns in AspsnD1 were not only audibly conspicuous at data sampling but were also associated with associated forward jaw movement at TZn ,followed by .forward and upward jaw movement and in drawn rounded lips (9.2) instead of normally protruded lips at the articulation of [o]. These are conspicuous in her back-TZn articulations and in some of her back- DZn articulations. Similar movements were observed at articulation of back-DZns in other D1 participants of much shorter durations.

9.2. Associated with upward jaw movement in 9.1 is rounding of lips, resulting inward non compressed lip corners, with lip rounding. The lips are also drawn inward for lip rounding.

This can also be called as rounded open exo- labial articulation because only the outer edges of lips are visible with lip roundedness in open position .

9.3. Similar movements are noted in AmssnD1, CmssnD1 and Aspsnsib2D1 at some of their back DZn articulations. But these movements have a long and clear cut visibility at TZns in this participant.

9.4. No articulatory observations are evident at front TZns in CmssnD1 who also evidence of back DZns with some instances of movements in 9.1 and 9.2**.**

10 .Vowel shift framework to back TZns - Her TZns indicate mergers on posterior vowel floors with expansion and mergers (Gayathri 2019 , vowels IV , submission to LII) an extension of back DZns (Gayathri 2019, vowels V , submission to LII) illustrated in figure 2 .

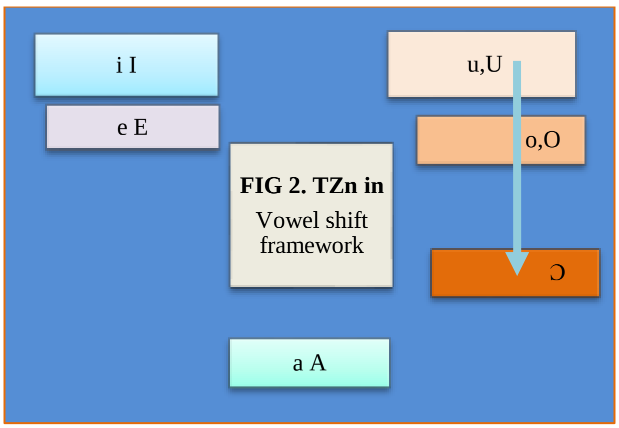


FIG 2. TZn in Vowel shift framework

Thus, the speech corpora contained vowels with phonetic accuracy and residual TZn substitution errors (Gayathri 2019, I). Thus, section 8.2. Indicates phonetic variability of vowel articulation between accuracy and back TZn in above phonotactic constraints.. In addition, a similar context has yielded DZn in *t{**uO**}(**O**){L}(r)isbeDA*. 8.1 indicates lexically confined sporadic front TZns in D1.

11. TZns are absent in D2 and D3 speakers in general. Only one instance k{u<o<Ɔ<}(o)DbEk{A~}(A)dr{e~}(e) of TZn with shorter phonetic elements is however seen in a d2 speaker .These participants are also fluent speakers with a more advanced artciulatory , speech and language acquisitions .

Discussion

TZns are substitution errors in speech of congenital SNHL , not reported in speech of congenital SNHL by other investigators since 1936 when first report was published as a thesis by Numbers F C . This was noted at the time of identification and sorting of vowel errors in conversational speech corpora in SNHL(Gayathri 2019, Vowels II, submission to LII).Multiple and open speech sampling in natural dyadic conversation tasks through TELS-HI /Kannada (Thirumalai and Gayathri 1982, 1998) has facilitated capture of TZn data . Two types of TZns are identified in three out of a total of 18 heterogeneous SNHL populations in D1 and D2 speakers . In D2 speaker TZn was however a sporadic single sample in his fluent speech corpora. [aei] /[-e] and [uoƆ]/ [-o,O-] were two TZn types observed in the three participants . Moreover, in CmssD1 front TZns were constrained to only a same lexicon with 4 occurrences .

Back TZns [-uoƆ-]in AspsnD1 occurs only medially with vowel [o,O] in medial retroflex consonant and cluster phonotactic contexts. Thus, a possible coarticulation mechanism underlying TZn is speculated. Unlike back DZns (Gayathri 2019 vowels series V, submission to LII), instead of occurring in broader contexts of anterior coronal articulatory consonant and clusters in similar contexts, the TZns are further constrained to retroflex consonant and retroflex cluster contexts. But, they do not occur at every medial retroflex consonant and cluster phonotactic contexts as can be seen in 8.2.3. There is a possibility of DZn occurring in similar contexts .Further, vowel [o,O] are either articulated with accuracy (e.g. in 8.2.1) or substituted by vowel [e] in one lexical context . Resulting TZns in these contexts of high mid back vowels are also confined to backness of tongue. No TZns are seen in her front vowels . However, every TZn occurrence is associated with solely above retroflex consonants or their cluster contexts. TZns are substitution errors in speech of congenital SNHL . The vowel [o.O] is word medially in free variation with DZn [uo] types and TZns [-uoƆ-] in general in the retroflex phonotactic constraints .

An AspsnD2 speaker also showed only one evidence of TZn in his fluent speech corpus k{u<o<ɔ<}(o)DbEk{A~}(A)dr{e~}(e). Hence, no analyses is made on this rare TZn sample in single lexicon .But what is consistently evident is that like in AspsnD1it has occurred medially in context of [o] with its post vocalic retroflex cluster context . It is not known if he had many such errors developmentally in his speech . Further ,his TZn is compressed with short durations of all three vowel elements . Other D2 speakers in his group have no evidence of TZn .Summing up , D2 speakers have overcome TZns in general like the D3 speakers .

If TZns are considered under the frame work of vowel shifts (Gayathri, IV, 2019 submission at LII), Back TZn is an extended merger occurring in posterior vowel articulatory is a severe 'merger' with expansion of back vowel floors to[Ɔ].But frontal TZn in CmssnD1 does not confine to same position of lingual backness. The phonetic elements in [aei] traverse from low **central** to **front** high mid, high lingual floors. When this child participant is compared with similar AmssnD1, the latter has no TZns.

CmssnD1

As regards TZns in CmssnD1, no inference can be made for two main reasons. This because they are not only sporadic but also confined to specific word. Hence this could be a wrong learning of the lexicon *ide* articulated as *yide* by native Kannada speakers . But this argument goes completely unacceptable as there are evidences of accuracy in lexical articulation of [e] in same lexicons *yide* , *y{I>}(i)d**e.*** When her other vowel errors on vowel [e] is considered [a], [i],[ae] swap vowel [e] in lexicons . In addition , the phonetic elements in [aei] contain these substituted vowels [a][i] in addition to target vowel[e] as its elements . She also has DZns [uo] [ou][ei] and [ie] in her speech corpora . However, back TZns are absent in her speech. In medial, retroflex contexts of [o, O] with retroflex consonant contexts, too she has only back DZns of [uo] types and no TZns . It is highly probable that, frontal TZn is a developmental behavior with lexicon *ide* or *yide* with accuracy of lexical articulation and indecisive phonetic lexical expression for same semantic concept *ide* 'is there'. As it is bound to this specific lexicon only and supported with accurate word final vowel [e] accuracy in other lexical examples, contexts *yell{A}(i)d**e*** , *{k}(h){ae>}(E)g**e** ba{dd}(nd)**e***, *{s}(sk)Ulig**e***, *ga{TT}(NT)**e***, *a{L*}Ed**e***. Probable indecisiveness phonetic selection at the time of phonetic articulation of lexicon ide could be the contributing factor having seen either [a] ,or [i] as monophthong substitutions for same lexicon at vowel [e] articulation in other conversational contexts, in addition to accuracy of vowel [e] articulations . AmssnD1 compared to this CmssnD1 has sporadic back DZns only and he has no TZns in his speech corpus.

AspsnD1

A reconsideration of comparisons of observation of medial [o,O] with retroflexes in other D1 speakers with above AspsnD1 speaker with TZn is illustrated in this paragraph . Following findings are enumerated on this aspect . In this group, D1 only two Aspsn including the Aspsn with TZn in the current study and AmssnD1 are fluent speakers . All other speakers in D1 are less fluent ,with relatively limited vocabulary in their speech corpora . Where a nominal few of these contexts arise they are DZd. And some retroflexes are also misarticulated with other place of articulation substitutions nullifying the retroflex articulations . But, in D1, only another AspsnD1 and AmssnD1 are the participants who have similar frequency of occurrence with phonetic constraints which has shown susceptibility for TZn in AspsnD1 . Both these speakers in these contexts do not show DZns . In fact, this second AspsnD1 fluent speaker has no residual vowel substitutions at all . The AmssnD1 has no TZns in these contexts with only a few DZns in his repertoire . This is because, most of his retroflexes are misarticulated with corresponding anterior dental consonants. Thus ,it is only the AspsnD1 with TZn who has many retroflex consonants contexts in her conversation repertoire ,having acquired them partially .Her homorganic retroflex consonant clusters are substituted by single retroflex consonant itself , thus also providing for retroflex consonant context samplings . Other than these, she also has many geminate retroflex clusters in addition to single retroflex consonants in medial lexical contexts .some of her heterorganic retroflex clusters are misarticulated with either vowel insertions or absence of retroflex consonants . Thus, AspsnD1 with large number of vocabulary in her speech corpus has multiple contexts of retroflex consonant and their cluster acquisition phases , with expressions of either DZns or TZns or vowel accuracy when associated with medial [o,O] vowels as described earlier . They are in free variation with DZns and accuracy in vowel articulation with specified variabilities .Further, three similar Aspsn in domain D2 have also overcome TZn in their dyadic conversations as a group, though an evidence of TZn is seen in one AspsnD2 who has a single evidence of TZn only.

Observations of AspsnD1's conspicuous TZn artciulatory movements at data sampling with integrated with TZn transcription.

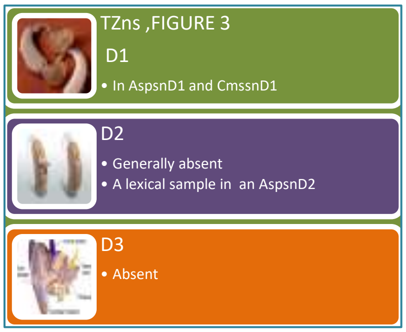
Both front and back TZns are substitutions for corresponding high mid vowels. They are absent in high vowels and low central vowels. However, they are spread in both front and back vowels. TZns in AspsnD1 are of conspicuous nature with audibly and visibly conspicuous associated jaw and inward drawn lip movements (9) at some of these TZns in AspsnD1. They first appear like exaggerated movements at these instances .In fact they are articulatory processes involved in back DZns, not observed in other instances other than at some back DZns. In addition, why vowel [u] is not TZd like high mid vowel is not known, even though it shows DZn substitutions. What is audibly evident and transcribed of back TZns [uoƆ], is indicative of constant lingual posteriority and lip roundedness. The lingual movements transcend from high to low-mid vowel floors with increased lingual backness at completion of its articulation. In this context it is appropriate to recall Ling's (1976, pp 118) statements who emphasized that we cannot be satisfied if the child produces vowels that are acoustically acceptable unless they are also produced with appropriate adjustments of the tongue, lips, and jaw, which needs attention in speech therapy . Another observation regarding articulation of back vowel [o, O] is that the posterior nature of vowel and roundedness dimension of these vowels is maintained but the precision and steady state of lingual height at high position is spread across high, high mid and mid low positions by substitution with TZn [uoƆ]. They are further, subjected to durational variances of its phonetic element .

Back TZns in retroflex and their cluster with medial high mid vowel phonotactic lexical constraints are indicative of definite co articulatory effects. In these TZn contexts are identified definite post vocalic (o,O) retroflex segments in lexicons .

Why back TZns are prominent only in Aspsn in D1: Plausible explanations

Operation of the process TZn in a D1 speaker AspsnD1 eventually leads to constricted proportion of pure vowel inventory in SNHL speech corpus. These participants also have DZns in their utterances. Two other speakers have rare TZn. It is evident from above analyses that advanced hearing devices D2 and D3 exclude TZn defects and in low frequency residual hearing AhifsnD1 also. As a result, they maintain normal vowel and diphthong ratio in their speech corpus. In addition, other D1 speakers ApsnD1, other ApsnD1, and AmssnD1 have no DZns in their speech repertoire. While AmssnD1 has better hearing than AspsnD1 participant who presented TZn, contradicting this is Apsn who has profound SNHL. Why this indiscrepancy is associated with severity of hearing loss is answered by speech and language acquisition status in the AspsnD1 participant with TZns. As speech acquisition progresses new articulatory challenges have enforced additional speech defects such as TZns in contexts of lexicons. Thus progress in speech and language acquisition does not totally ensure ,better speech outcomes until complete normalcy achieved .The speech disordered population face new challenges of coarticulatory nature with enhances in articulation and language developments . This particular D1 speaker in addition, is also an early identified congenital SNHL , with immediate initiation of D1 rehabilitated hearing domain and LT-CAOSLT. She not only has many retroflex speech vocabularies in her fluent conversation corpus but also compound and complex lexical formations with application of agglutination rules. Thus, many of her words also encompass longer phonetic strings. In addition, she is more advanced than several other D1 speakers who has overcome front DZns which is a developmental issue in congenital SNHL (Gayathri 2019, vowel series V, submission to LII). She also has overcome DZns in other medial anterior coronal articulatory contexts, except in the medial [o,O] associated with retroflex consonant and their cluster contexts . TZns is an extension of this behavior in this AspsnD1. Further, in those lexicons where she has misarticulated medial retroflex consonants and clusters with other anterior coronal consonants in context of medial [o,O] she has no DZns. E.g.: *ko{l}(L)a , wO{l}(D)ADabEku, nO{t}(Dt)A, biDO{n}(N)a ,nO{n}(D)ONa, nO{n}(D)ONa, {m}(b)i{n}(D)ONa, taeko{nn}(ND)U, sA{t}(nt)O{s}(S)a, ko{n}(+)bba{n}(r)I, {r<}(r)a{g}(ng)Ole, mOsara{nn<}(nn)a, mo{nn<}(nn)e.* Examples of vowel accuracy articulation in 8.2.1.in medial vowel [o] with retroflexes in lexicons also indicate the acquisition processes of normal vowel articulation in these specific coarticulatory contexts lexicons. Another

AspsnD1 who also is a similar advanced fluent speaker with less number of complex lexicons has overcome all vowel defects in his speech corpora with residual disorders of vowel duration and nasalization. He has better vowel articulatory acquisition amongst all AspsnD1 speakers and even so amongst D1 speakers when AhifsnD1 is excluded from this group.



Being a vowel Substitution error the TZns are also rule governed which present a differential distribution in congenital SNHL subjects in this study. Even though vowel error variability is generally presumed, these regularities of TZn occurrences captured at dyadic conversation implicate definite speech therapy measures to overcome these coarticulatory TZn residual vowel errors. They have also manifested exolabial inward rounded articulations at data sampling like some back DZns. The TZns are absent in D2 and D3 speakers in general (figure 3). In D1 speakers, it is seen in two participants, both of whom also have DZns in their speech corpora .But, the phonetic contents of TZns are different. Only back TZns in AspsnD1 is patterned due to sufficient lexical samplings with TZns in AspsnD1 data. It is governed by consistency in phonetic structure and lexical phonotactic constraints in conversational corpora.

Conclusion

Novel back -TZn errors as vowel substitutions with inward rounded exolabial, non compressed articulations' are identified in D1 congenital SNHL speakers. They show consistency in lexical phonetic constraints in which they occur. Those participants who presented TZns in general also had DZns in their speech. In depth, study of front TZns was not possible due to their limited samplings and single lexical specificity . TZns are absent in D2 and D3 speakers, like DZns identified in pervious study (Gayathri 2019, vowel series V, submission LII)

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7

Salient parametric pointers to random residual vocalic nasalization occurrences in dyadic conversations of congenital SNHL with contemporary hearing devices VII.

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Abstract

An exploration of Kannada conversational speech corpora for the identification of residual vowel NZns in D1(analogue behind the ear level hearing aid users) , D2 (programmable behind the ear level hearing aid users) and D3 (multi channel cochlear implanted) hearing domains of congenital sensorineural hearing loss (SNHL) who had completed long term comprehensive oral aural speech and language therapy . An important finding is the persistence of residual vowel NZns in all three hearing domains in general and there were also exceptions to this rule. Participant speech corpora analyses generated several stratified idiosyncratic consistent findings and ambiguities and of vowel NZn occurrences. An atypical synchronous vowel NZn behavior and cul de sac hyper nasal speech quality lead to possible speculations of unified overall mechanism in at least some proportions of NZn of vowels in speech of congenital SNHL. Adult high frequency SNHL in analogue hearing aid users demonstrated good projective speech quality with zero vowel NZns .Degree of SNHL in D1was a contributing parameter to consistencies in vowel NZn occurrences in conversations. Hyper nasality is not a steady feature in conversations. Multiple factors to occurrences of obstinate residual vowel NZns in conversations of SNHL emerge from current study.

Keywords: nasalization, vowel, hyper, hypo, nasal, cluster , consonant ,vocalics, hearing impaired, deaf, cul de sac, clusters, articulation, lexicon , compensatory ,congenital, sensorineural hearing loss, analogue BTE , programmable digital BTE , cochlear implants , conversation, corpora ,paradox, coarticulation, phonetics.

Introduction

Nasalization (NZn) of vowels is commonly reported in pre lingual congenital SNHL disorders (Figure1), since the use of conventional hearing devices up to modern day multi channel cochlear implantations

(Numbers (1936) ,Hudgins and Numbers(1942) , Thirumalai & Gayathri 1980,1988; Osberger& Mc Garr (980, Svirsky & Chin 1998; Kim, Yoon , Kim, ,Nam, Park & Hong 2012 ; Baudonck, Lierde, Dhooge& Corthals 2011; Gayathri 2016). Many reasons are attributed to the persistent occurrences of vowel NZns in congenital SNHL. Beginning with Bell's suppositions (1906) of pharyngeal constriction and habitual depression of soft palate as primary reason, many studies for vowel NZns in congenital SNHL can be traced in literature. After more than a century yet, in the modern advanced cochlear implanted D3, vowel nasalization is hitherto a prevalent phenomenon in the prelingual SNHL (Baudonck, Lierde, Dhooge & Corthals 2011, Gayathri 2016, 2019c). Recent studies in Kannada have identified vocalic NZns which includes pure vowels, diphthongization, triphthongizations, V –V hiatus, substituted alien vowels, substituted defective vowels , vowel insertions between consonant clusters in lexical contexts also get nasalized(Gayathri 2016, 2019c) .These are broadly termed as vocalic nasalizations .

Degraded auditory feedback (Ling 1976); poor compensatory oro- sensory feedback for velopharyngeal - valving actions (Ling 1976, Kim, Yoon , Kim, Nam, Park & Hong 2012) ; cul de sac resonance and lingual retraction (Boone 1976); slow speech rate (Colton & Cooker 1968; Fletcher & Higgins 1980) are some rationales to vowel nasalization in congenital SNHL speech . Connected to nasalization in SNHL are also narrow vowel space (Shukla 1988, Monsen 1983) and possible retraction of tongue through acoustic studies (Monsen 1983). Acoustic assessments of nasalized vowels are also undertaken by many researchers (Stevens 1976, Chen 1995, Scwartz 1987, Monsen 1983). Baudonck, Lierde, Dhooge& Corthal's (2011) study has further confirmed that the prelingual hearing aided and cochlear implanted SNHL groups are at risk for nasalization.

Kim, Yoon , Kim , Nam, Park & Hong's (2012) recent study indicates existence of hyper nasality , hypo nasality and mixed nasal groups in prelingual hearing impaired speech. They attributed velopharyngeal function as directly related to nasalance of vowels .The HI hyper-nasal group showed tendencies of velopharyngeal opening, as opposed to the HI hypo-nasal group who showed tendencies of velopharyngeal closure. The HI mixed-nasal group showed inappropriate coordination of velopharyngeal function. They suggested VFR tool explains the focusing characteristics of resonance energy within a continuation of speech sound regardless of the phonetic environment.

Focus of current study is exploration of nasalized vowels in lexicons from conversation data in different hearing aid users D1, D2 and D3 (Figure 2, 3, 4). Like all other previous study in vowel series, vocalic NZns comparisons are made between analogue behind the ear (BTE) hearing aid users (D1), programmable digital BTE hearing aid users (D2), and the cochlear implanted (D3). Having identified vowel nasalization as one amongst vowel error typologies in previous research (Gayathri Vowel Series II, 2019), the purpose of this study is to identify organized patterns of vocalic nasalization in their natural conversation task. Vocalic or vowel nasalization which was classified as similar substitution had presented enormous variability in conversation speech data bases in Kannada. No specific probe into nasalization in congenital SNHL is available in Kannada.

Methods

This study is a part of ongoing parent study on conversational speech of congenital SNHL begun in 2007 .The parent study contains 18 congenital SNHL subjects who had completed intensive long-term oral-aural speech and language therapy. Their mother tongue and regional tongue was Kannada. They also wore three different contemporary hearing devices: Analogue BTE hearing aid, Digital behind the ear hearing aid and the Cochlear implanted named as D1, D2, D3 rehabilitated hearing domains (see figures 1,2,3,4) . Table1 provides clinical details of 18 participants in this study.

Figure 1. Affected parts of ear in irreversible congenital SNHL.

Figure 2: D1, Domain 1, Analogue behind the Ear Hearing Aids.

Conversation section 12.3, of a test coined as TELS HI /Kannada developed at Central Institute of Indian Languages; Mysore (Thirumalai and Gayathri 1982, 1988) after many years of its clinical use was administered to the congenital SNHL participants in a silent room in face-to-face context. The same was recorded with high quality Sony digital audio recorder connected to high quality microphone. Perceptual approach was adapted to make judgments of vowel phons and transcriptions.IPA transcription was adapted with fine attributions where needed for phonetically abnormal word units up to their utterances. Further details of methodology adapted can be seen in Gayathri (Vowel I, 2019).

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Figure 3. D2, Domain2, Digital Programmable Behind the Ear Hearing Aids

A novel approach to document lexical transcription was adapted. Word by word transcription was undertaken systematically in each lexical transcription, flower brackets are used for subject's phonetic segment misarticulation with target phone written in regular brackets adjacent to it. E.g. if [ADalla] is target lexicon, misarticulated phones within this target lexicon was documented as [A{d}(D)a{l}(ll)a].IN [A{d}(D)a{l}(ll)a] those phones in flower brackets are defective : {d}and {ll} . Their target phones are [D] and [ll] are by their side in regular brackets. This approach provides for simultaneous phonetic examination of the error word with normal word within square brackets. It also facilitates for simultaneous analogous examination of abnormal phonetic segment with target phonetic segment in flower brackets and regular brackets in their lexical contexts. In addition, nasalization of vowels is marked with symbol~ which is the focus of current study.

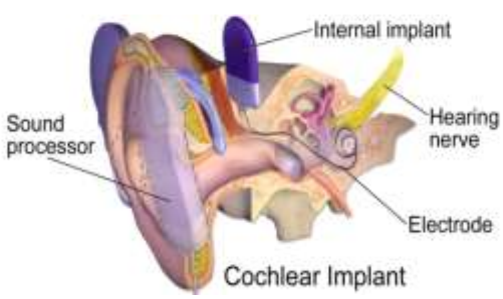

Figure 4 D3, Domain3, the Multichannel Cochlear Implanted

By skipping flower brackets participants target word is read, and by skipping regular brackets, misarticulated word is read. By observing, the units within square brackets judgments were done in word context. Thus, the phonetics of target and participant's phon production can be compared in this method of new coding providing space for uttered word contexts.

Next step involved data searching and delineation of nasalized (~) vocalic errors in the speech corpora marked with ~ in participant's inventory, such as the vowels, diphthongs, diphthongizations or triphthongizations in speech corpora . By itself symbol ~ in running text indicates nasalization of its associated vowels or vocalic segments. Nasalized vowel of participants from transcribed data bases were extracted and tabulated in their lexical contexts. This data was then examined and analyzed from various angles to identify distinguishing patterns and characteristics of vocalic ~.

1. Apsn Domain1
2. Aspsn Domain1 n=2
3. Amssn Domain1
4. Ahifsn Domain1
5. Cpsn Domain1
6. Cmssn Domain1
7. Apsnsib2 Domain1
8. Aspsnsib2 Domain1
9. Aspsn D2 Domain- n=3
10. D3 Domain - n=6

All participants except CpsnD1 and CmssnD1 had completed speech and language therapy
D1= Analogue BTE hearing aid user, both ears
D2=Digital programmable hearing aid user. All were children, both ears
D3= Multi channel Cochlear implanted (in one ear), age @sampling – 8-10 years, post speech and language developmental period
Sib2=second congenital SNHL sibling in family
C, D1= child, ongoing speech therapy and language experience for 7 years, parallels with child D3
A=Adult
Criteria of sampling – Completion of long term aural- oral speech and language therapy, congenital bilateral symmetrical SNHL, main streaming to normal schools;
Incidental Sampling; Total n=18
TABLE 1
(More details in vowels series paper 1,Gayathri 2019)

Table 1 Participant details of current study

Identification of vocalic ~ patterns driven by nasal segment environment in lexicons are the primary focus of current study. The findings from analyses and observations of extracted data are presented below. Where abnormal resonant characteristics of speech are conspicuous, they were also documented as average, hyper nasal, or hypo nasal speech, Cul De Sac resonance in their profiles. They were then examined to identify if any association of vocalic NZn exists with different speech quality types.

Results

Findings from current study indicate that vocalic ~s in lexicons of congenital SNHL are a complicated and stratified processes, influenced by many parameters in participants' speech corpora and Kannada's nasal segments. They occur in all three hearing domains D1, D2 and D3 in a range from frequent, few, episodic, sporadic, to absent NZns. They occur in both ambiguous and consistent associations with nasal segments in lexicons. The D1 as a group demonstrate ambiguous patterns unlike their other vowel errors such as the diphthongization error typology, substitution error typology presented in previous papers in vowel series (Gayathri 2019c, d, e, f vowels- II, III, IV, and V) . Nasalization tokens denote nasal consonant segment lexical contexts .But; in other vocalic samples are also their non occurrences in similar contexts thus indicative of their variable nature. Nevertheless, a few other lexico- phonetic contexts implicate definite conditioning by nasal consonant phonetic segments to vocalic nasalizations in D1. However, it is emphasized that, only AhifsnD1 has no vowel NZns in her speech corpus. Included below are different findings on vowel ~ amongst groups D1, D2 and D3. There are also differences in consistency of organization of nasal vocalic segments in conversational speech with decrease in degree of SNHL in D1.

Distinguishing attributes of vocalic nasalizations in D1 speakers.

It s emphasized that the speech corpora of D1 speakers comprise many misarticulated vowel segments. Their conversations comprise many non pure vowels broadly termed as vocalics as mentioned before. Hence, data driven analyses of nasalization in participants' speech corpora yielded association of many types of vocalic segments with nasalization. Hence, the normally articulated vowels, substituted vowels , diphthongs, diphthongized segments, triphthongizations, V.V hiatus are vocalic segments within lexical contexts examine NZn. Coalesces of nasalized vowels with other vowel error typology (Gayathri Vowel Series II, 2019) are in addition documented at analyses. Results of two main aspects of vocalic nasalization's are presented in following sections. 1. Type of vocalics which are susceptible to NZns in D1 and 2. Vocalic NZn occurrences adjacent to nasal consonant segments in corresponding lexicons suggestive of possible coarticulatory impacts in D1 are presented under sections 1 , 2, and 3 respectively and in figure 5,6,7 and table 2 .Other data driven findings on vocalic ~s are also listed in following sections

1. **Vulnerable lexical positions of vocalic nasalizations** Nasalization of vocalics occurs in all three lexical positions in conversational data: initial, medial and final (table 2).

1.1. **Normally articulated vowels** in natural speech may get nasalized. E.g. *m{a~}(a)ne ,mane in D1 and y{A~<}(A)km{A~}(A)DbArdU in D2* and *oL{A~}(A)ge~* in a D3 participant . Hence, arises the issue of variability of ~. These can be grouped as similar substitution typologies depicted in previous papers (Gayathri 2019, vowel series II).

1.2. Some **substituted vowels** are also coalesced to nasalized vowels *{E~}(a)ngaDi in; E/a* coalesced in D1 and *h{ƆƆ<~}(O)gbOdu in D2* .

1.3. **Diphthongs** of Kannada which are faintly distributed in Kannada inventory are also overlaid with ~. *k{ai~}(ai), m{ai~>}(ai){t}(s)Ur.*

1.4. Nasalization is also a characteristic feature of substituted **diphthongizations** for target vowels. Both types of common diphthongizations , the front and back for e.g. [uo]and [ei] [ie] are affected with nasalizations e.g. *b{aeae)(e)nk{i~e<}(i), {t<d}(d){u<oo~}(O){nn}(N){a}(i), m{A~>}(a){w}(dw){ei~<}(e), m{u<O~}(U)ru, {t<d}(d){u<O~>}(O){n}(N){i~}(i)* . This is again found to be a variable feature E.g. *(w}(d){u<O>}(O){n}(N)i.*

1.5. **V.V hiatus** reported in previous papers (Gayathri 2016, vowel series II Gayathri, 2019) also exhibit ~. E.g. *m{a~}(a)nE~.i(-l)')* . Similar finding was also seen in D0 in preliminary study (Gayathri . 2016). The ApsnD0 body level hearing aid user(D0) in previous study also had showed nasalization in these contexts with variability . e.g. *mai{t}(s)U{r*}(r){A.a~}(-r)')m{a~}(a)nne , r{A.u~}(-jk)')(u)mAr , r{A.u~} (-jk)')m{A~}(A)r , {r<}(r){A.u}(-jk)')m{A~}(A){r<}(r) , m{a~}(a)n{E~.i}(-l)'* (Gayathri 2016). Whether nasal consonant in lexical environment are influencing nasalization of V.V hiatus in such examples is speculated.

1.6.. **Nasalizations appear in coalesces** with other vocalic defects such as duration deviations, substituted vowels, diphthongizations which may result in formation of complex vowel phonetic structures . For example, combination of long vocalic or reduced duration with ~ can be observed in e.g.*{t<d}(d){u<oo~}(O){nn}(N){a}(i), m{A~>}(a){w}(dw){ei~<}(e), b{e~<}(e){l}(L){a<}(a){K}(k)u, {A~>}(A)m{AA~>}(E)((le-), {a~}(A)m((Ele-* **,** *n{A~>}(a){nn>}(n)((ge-) n{AA~>}(a){nn>}(n)((ge-* .

1.7. **Variability of vocalic nasalization in similar successive lexical outcomes** or in lexical recurrences in conversation speech samples is observed . E.g.: *{t<d}(d){u<O~>}(O){n}(N){i~}(i), (w}(d){u<O>}(O){n}(N)i, n{O~}(O)Dde, (n-){O~>}(O)D<da.*

1.8. **Coarticulatory vowel specificity to nasalization** This is idiosyncratic in D1. In Amssn , Cmssn and Aspsnsib2 D1, vowels [a],[A]showed higher susceptibility to nasalization in the contexts of bilabial nasal segment [m] and geminates [mm] (see clause 2.5 and 3.2 below).

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1.9. **Phonetic complexities of nasalized vocalic** decreases from highly complex vocalic phonetic structure to lesser degree from Aspsn to less severe degree of SNHL, the Amssn participants in D1. e.g. {u<oo~}(O)in Apsn D0 versus {O~}(O)or {O~>}(O)in Aspsnno1D1.

Table 2. susceptible vocalic segments for nasalization A, and nasal consonant environments which condition NZn B in D1	
***A**. List of patterns of Vocalic segments which undergo ~ in conversation*	***B** List of nasal segment environments which condition nasalization of adjacent vowels in lexicons in conversation*
Dotted lines indicate interaction of elements in list A with those in list B	
Susceptible positions in lexicon vulnerable for vocalic nasalization : either initial, media or final	*Nasal consonant environments of either accurately articulated nasal consonar or defective nasal consonant*
Normally articulated vowels Diphthongs of Kannada D1 , D2 D3	*Not a single ~ occurred in oral nasal articulatory transient consonant environment*
Substituted vowels in D1 , D2	*Contradictory examples of occurrences of vowel ~ in purely oral consonant lexical environments.*
Diphthongizations	*Variability*
V.V hiatus	*idiosyncratic : nasal consonant [m] implicated a greater tendency for vowel nasalization in lexicons*
In coalesces with other vocalic defects such as duration deviation ,Substituted vowels, V.V hiatus , Diphthongizations	*geminate nasal cluster contexts*
Variability of nasalization is possible in similar successive lexical outcomes or in lexical recurrences in conversation speech samplesD1,D2, D3	
Phonetic complexities of nasalized vocalic decreases from highly complex vocalic phonetic structure to lesser degree in Aspsn and Amssn participants respectively in D1	*Idiosyncratic Vulnerability NO- HMO segments : Homorganic cluster contexts:* *1. normally articulated> ~* *2. NO HMO > de nasal consonant , denasal geminates >no~* *3. nasal consonant >no ~* *4. Transposed NZn : NO–HMO [nd] is substituted by oral consonant [d]. But it's previous adjacent vowel in this word is nasalized*
Idiosyncratic *Vowel NZs occur in NO-HMO consonant cluster*	*Idiosyncratic Vulnerability adjacent to NO- HMO segments : Homorganic cluster contexts:* *1. normally articulated> ~* *2. NO HMO > de nasal consonant , denasal geminates >no~* *3. nasal consonant >no ~*
Vowel NZs occur in consonant cluster simplification context with insertion of vowel nasal consonant elementsD1	*Heterorganic cluster with nasal consonantal element simplification and vowe insertion. This vowel >~*
Idiosyncratic Vowel specificity : NZn of vowel [a] and [A] get NZd	*Idiosyncratic vulnerability of [a]and [A] in [m][mm] in mssn [nn]i also n CmssnD1.*
Idiosyncratic *Transposed preceding vowel NZn D1*	*On adjacent vowel when a nasal consonant s deleted*
Idiosyncratic *Transposed preceding vowel NZnD1*	*On adjacent vowel when a nasal consonant element in NO – HMO luster is*

	deleted
D1 ***medial vowels***	*When a lexicon has two successive nasal environments medial vowels are bound to be nasalized*
D1 *Vowel nasalization occurrences are completely absent in stressed words which had NO- HMO cluster as element*	
Other contributing parameters for ~ in conversations of congenital SNHL	
1. *Type of hearing device use is an important parameter*	
2. *Degree and type of SNHL in D1 is an important factor . AhifsnD1 has no vowel NZns. And patterns of vocalic NZn occurrences vary with different degree of SNHL in D1*	
3. *Only exception for NZn behavior in D1 is AhifsD1and AhifD0 – zero vowel NZns*	
4. *AspsnD2no1- Atypical NZn in alternating speech with cul de sac resonance. Other two speakers in D2 had no NZn*	
5. *D3 speaker sporadic in one participant .all other 5 speakers had no perceptual NZn*	
6. *Speech Nasality – hypo nasal ,average ,hyper nasal , cul de sac*	
7. *Nasality occurrences – sporadic , Overall , @conversational repair, not seen in stress ,derailment at conversation , alternating speech bits*	
8. *Depending on the degree of hearing loss ~ expresses from highly ambiguous to partially ambiguous to definite conditionings of vowels in specific nasal segment contexts in D1*	
9. *NZn is complex behavior in conversation of congenital SNHL, influenced by the reference target Kannada language inventory and participant specific inventory with interaction of A and B listed above ,type of device use and residual hearing*	

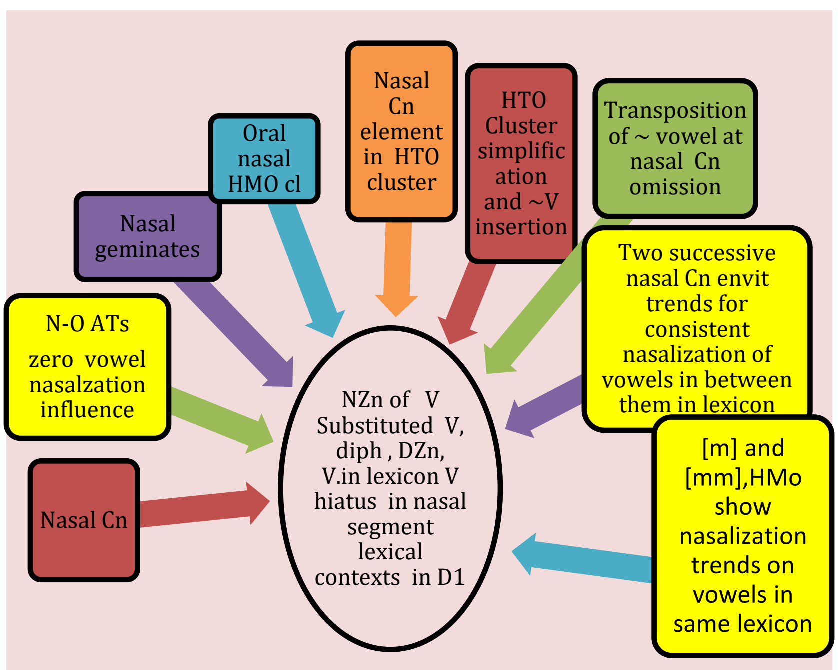


Figure 5. Vocalic segment ~ and adjacent nasal segments embedded in conversation samples in D1

Thus, both similar and dissimilar substitutions had presented with vowel and vocalic nasalizations inD1. Some idiosyncratic vocalic susceptibility patterns were identified in this group.

1.10. Vowel NZs occur **in vowel additions in consonant cluster simplification context** with nasal consonant elements *{A+}la(kASA~mm)(kS m) i.*

2. **Coarticulatory vocalic NZn occurrences adjacent to nasal consonant segment in lexical context**.

2.1. Nasal consonant environments of either accurately articulated nasal consonant e.g. *m{A~>}(a){w}(dw){ei~<}(e), kyaeae~ma~lA, myaeae{L}(D)A~m*; or defective nasal consonant condition nasalizations of their adjacent vowel e.g.. *{t<d}(d){u<O~>}(O){n}(N){i~}(i).* In this example nasal consonant [N] is substituted by [n] which yet influences adjacent vowel (o) and (i) for nasalization.

2.2. Not a single ~ occurred in substituted oral nasal articulatory transient consonant environment (see Gayathri 2016 for oral nasal articulatory consonant examples) occurred {*b<m}(m)aduve, A{p<m}(m)E{r}(l)e* .This is a consistent finding unlike 2.1 , 2.3 and 2.4.

2.3. In contrary, even though 2.1, indicates lexical phonological grounding to surface phonetic vowel nasalization at conversation, there are also contradictory examples of occurrences of vowel ~ in purely oral consonant lexical environments. *b{e~<}(e){l}(L){a<}(a){K}(k)u.,{a~}(a)kka*

2.4. 2.1 and 2.3 did not occur for each similar lexical context in same participant thus indicating variability of ~ occurrences in D1.

2.5. Of all nasal consonants, [m] triggered a greater tendency for adjacent vowel nasalization in lexicons than [n,N]..This nature was idiosyncratic in D1

3. **Coarticulatory vocalic ~ behaviors adjacent to nasal consonant cluster lexical contexts**.

3.1. In **geminate nasal cluster** contexts there existed both vowel ~ impacts *m{A~}(a){nn}(n){A~}(E)* and its absence *{gg}(j){E>}(a){j}(y)A{nn}(n){A>}(a)g{a.a}(-r)'), {nn>}(n)a{nn>}(n)a{G<}(g)e*. An example of ~ in oral geminate context was also observed { a~}(a)kka. But, further examination of speech samples denotes presence of larger number of lexical samples with oral geminate plosives with no *vowel* **~ {***gg}(j){eE>}(a){yy}(y)An{A>}(a)g{A.a}(-r)'), (l-)){EE}(e)kka {I}(i)dd{A>.e}(-r)') ,(-g)){u<o}(o)ttilla,{E}(a)ttu, Ogutt{A}((Ini-) , ga{TT}(NT)e , yi{dd}(d)e, wOgiddae ,(A+){pp}(p)U{r>}(r)I {y+}{E}(a)kka* and others. But only rare examples of contradictory samples with oral geminates and nasalization of vowels in its contexts are present .e.g.:{a~}(a)kka

3.2. **Some Idiosyncratic vocalic ~ consistencies** Consistent nasalization is identified with geminate [mm] in lexical samples in CmsD1. .This consistency was unlike other nasal geminate clusters. e.g.*{a~}(a)mm{a~}, (a),{a~}(a){mm^}(mm) {a~}(a) {A+}la(kASA~mm)(kS m) i ,me{l}(D)A~mmu , t{a~}(a)mma , {E~}(A){mm}(m){a~}(E)((le-),*. Hence, [mm] geminates have stronger impact on vowel nasalization than [m] in this specific subject. E.g. *tt{a~}(a)me*, versus *Ame(-le), mUruw(e}(a)re* .But AmsD1 shows tendency for vowel nasalization in both [m] and [mm] contexts with vowel [a] .Similar findings are seen in Aspsnsib2D1.Conversely, oral geminates have less impact on adjacent vocalic ~s (3.1) .

3.3. No such tendencies as 3.2 are seen for other geminate nasal clusters. E.g. *ti{NN}(ND)I, madie(-g-)anna* in same participants as 3.2

3.*4*. **Transposed NZn to adjacent vowel** when a nasal consonant is deleted in word ,~ surfaces in adjacent lexicon .Aspsnno1D1 *(n-){O~>}(O)D<da* in Aspsnno1D1. In this example ,initial consonant [n] is omitted but adjacent vowel[o] presents ~.

3.5. Coarticulatory vocalic ~ behaviors adjacent to NO- HMO segments Homorganic cluster contexts in D1 lexicons is not only varied but they also have different impacts. These clusters may be either normally articulated or misarticulated as denasal consonant, denasal geminates or nasal consonant. Of these former denasal types of substitutions were common .

3.5..1. When these NO- HMO clusters are misarticulated as denasal consonant or denasal geminates e.g. *wo{d}(nd)E> , wo{d}(nd)E>, ba{tt}(nt)u, ko[b}(mb)u ,{A}(a)g(ng)i,* in ApsnD1no1; NZns are often absent .

3.5.2. However, there are lexical utterances in D1 wherein the NO- HMO segments are accurately articulated which influence nasalization of adjacent vowels , but not always e.g.: *bandi{Law}(lw)A, m{u~}(u)nde, s{i~}(i){mp}(mh)A>, g{ə~}(a)NTe {ə}(a)ngaDi, g{ə}(a)NTe* .

3.5.3. **Transposed nasalization of vowels** One more characteristic of vowel nasalization in NO- HMO context is evident. e.g. *ba~{d}(nd)e*. In this example ON –HMO [nd] is substituted by oral consonant [d]. But it’s previous adjacent vowel in this word is nasalized and therefore nasalization appears to be transposed.

3.5.4. **Coarticulatory vocalic ~ behaviors in HTO NO cluster Heterorganic nasal component cluster simplification** and vowel insertion *Ala{kASA~mm}(kSm)i, la{cum}(kSm)u* .But, due to variability exhibited no definite inferences can be made ..

3.5.4.1. In Nasal oral heterorganic cluster lexical environment. *{A+}tinDi, {t}(v)i{n}(gn){A~}(A)na* inferences are similarly ambiguous like in 4.4 and others above .

4. When a lexicon has **two successive nasal consonant segment environments** medial vowels are nasalized. *e.g. in AmsD1 CmsD1*.e.g. *n{i~}(i)mma , m{a~}(a)ndyAna , maisUr*ar*ama~ne*(table 3)

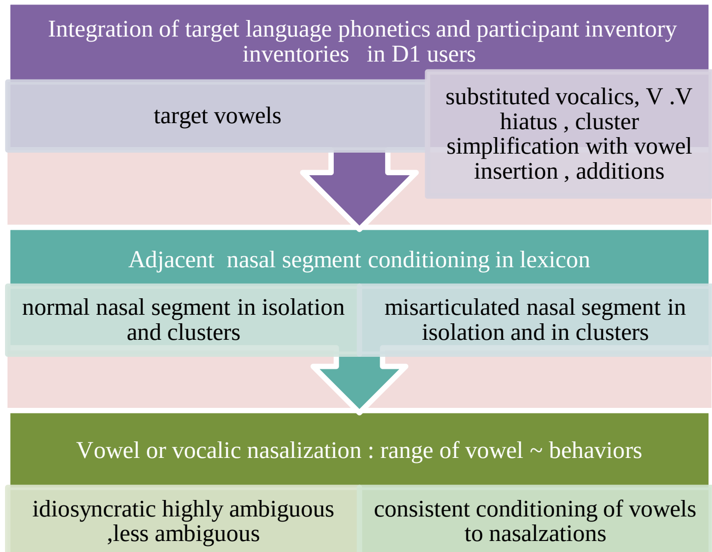
5. Spreading out of vocalic nasalization behavior in lexicons at conversational range from single vowel phonetic units to 2nd adjacent vowel unit or to vowel units in a stretch of whole utterance kyaeae~ma~lA~ . Such contexts specifically comprised of both anticipatory vowel nasalization and carryover nasalization effects. Maximum number of adjacent vowels influenced by nasal segments in lexicon are identified are three.

6. Stressed lexicons Vowel nasalization occurrences are completely absent in stressed words which had NO- HMO cluster as element in all D1 speakers. (See table 3 for samples in group D1).

7. **Perceptual fluctuations of vowel NZns** Some lexical contexts of vocalic NZns were perceived with greater degree of NZn than in other sections of dyadic conversations . Some lexicons with interaction of NO- HMO clusters with nasalized vowels are perceived with relatively high degree of nasalance. e.g. *.baeaenki~>e<, baeaenki~e<, si{mp}(mh){A~}(A) ma~ngge, E~mmE than si~mpA>* are perceived as more nasal perceived as much more hyper nasal than *summa~ne ,m{A~}(a)ne , E~mEl<e* nasalized vowel contexts . Similarly prolonged diphthongization coalesced with nasalization seen in ApsnD1 appears to be perceptually highly nasal -conspicuous speech -stretch e.g.: *g{u<O>~}(O){t}(tt)i{l}(ll)a*. A similar context is noted in preliminary paper (Gayathri 2016)with analogue body level hearing aid user , D0 e.g. : *{t<d}(d){u<O~>}(O){n}(N){i~}(i)* .

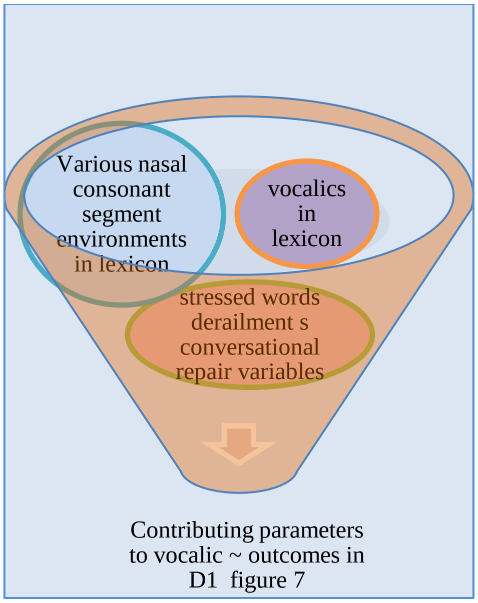
Table 3. Stressed Lexicons in D1 group
t{u<}(u){pp>}(mb)a,
t{u<}(u){pp>}(mb)a
tu{mp<b}(mb)a
tu{mpb}(mb)A
tu{mpp}(mb)a
tu{mp}(mb)a
tu{mpb}(mb)a
tu{mp}(mb)A
tu{b}(mb)A
nAwe{dd>}(ll)a<
illEE>(-v-)illaa>
bi<{t}(s)I<
bi<{t}(s)I<
u.i<(-r)')
bi{t}(s)Ibiti<
d{u<O}(o){ND}(DD)a

Figure 6. Interactions of vocalics with adjacent nasal segments in conversations



10. Deviant speech quality in conversations in D1 speakers.ApsnlD1 normal speech quality , except in *yee~nu mee~ku yee~nuuu with vowel nasalizations and cul de sac hyper nasal resonance.* This was an example of conversational repair and an emotional frustrated expression by the D1speaker. AspsnD1 no2 has hypo nasal speech quality .Both adult and child mssnD1 exhibit oral good projected speech quality . AspsnD1no1,and AspsnD1sib2 also have hyper nasal speech quality .Thus speech quality in D1 is heterogeneous ranging from good projected , normal , hyper nasal ,to hypo nasal types . hyper nasality could be of cul de sac resonance type in some participants as described below . No definite inference on nature of speech quality can be made in D1group in general.

Figure 7. Overall lexical parameters to outcomes of vocalic NZn in D1 conversations



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Thus , while vocalic NZns occur in all three word positions , there are at least some patterns of vocalic susceptibilities for vocalic nasalization occurrences in D1 even though in many nasal segment lexical contexts no definite inferences can be made . Interactions of vocalics with adjacent nasal segments in conversations yield vocalic ~s which are coarticulatory in nature. These patterns range from ambiguous to consistent patterns (figure 6 and 7) . On the other hand, vowels in stressed words in nasal cluster segment contexts and non segmental lexical contexts in 17 lexicons extracted fromD1 group listed under table 3 are not hyper nasal .But , some contexts of vocalic nasals are perceived with greater degree of nasality than others (7.). Contexts of conversational repair may cause change in base speech quality to cul de sac hyper nasal resonance (10) with NZd vowels .Some NZn behaviors are solely idiosyncratic in D1 . In addition, speech quality is a wide range from hyper nasality to good oral projections in D1. Observations on vocalic ~ with respect to severity of SNHL in D1 are presented in following sections.

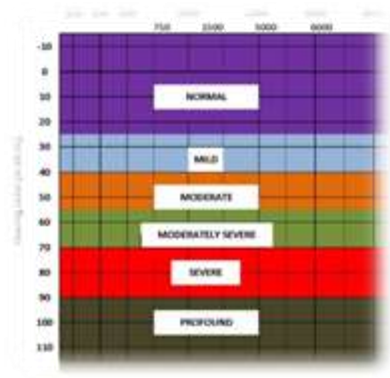
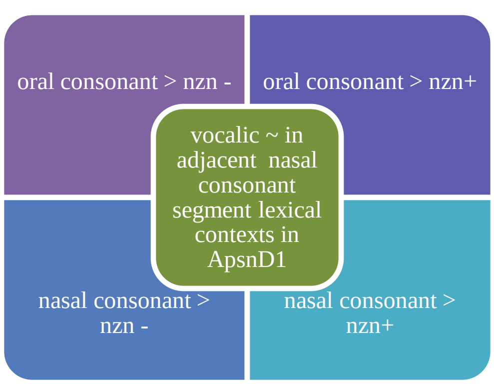


Figure 8. Audiogram indicating severity of SNHL

11. Severity and type of SNHL and vocalic NZn occurrences in D1: Following paragraphs further describes nature of vocalic ~s in different degree of SNHL . It is evident that AhifD1 do not have vocalic ~s at all in her speech .Profound SNHL (p),severe profound SNHL(sp) and moderate severe SNHL (ms)(figure 8) are different degree of SNHL in D1 participants in this study . It appears that findings on vocalic ~s are heterogeneous in these different degree of SNHL .

11.1**. ApsnD1** has ambiguous NZn behaviors. His NZn behavior is highly unpredictable and ambiguous. His ~ occurrences occur in both nasal and non nasal segment environments in lexicons as represented in the hit and miss matrix in figure 8.a . His vowel ~ 'hit and miss 'matrix covers all four vowel ~possibilities, leading to ambiguity for any conclusions on any organized behavior of vocalic ~ at conversation. An examination of another Apsn under D0 also exhibits similar high degree of ambiguity from preliminary data (Gayathri 2016) collected from D0psn, the body level adult profound SNHL speaker.

Figure 8.a. Highly ambiguous vocalic NZn in ApsnD1



His speech repertoires have clusters of only nasal and oral geminates. He has not acquired NO- HMO clusters. For NO- HMO contexts, he has substituted the corresponding oral consonant element. Nor, does he have NO -HTO clusters in his inventory. His vocalics in conversation comprised of normally articulated target vowels and many vowel error typologies such as the V.V hiatus, similar and dissimilar substitutions, which included substitutions and vowel diphthongizations. No definite lexical context, vocalic sensitivity, or nasal consonant specificity to influence NZn is identified. His vocalic NZn ranged from simple to complex coalesced phonetic structures e.g. [a~], [u<oo~] Neither is found transposed NZn tokens. Even though, his speech quality was average oral, there are sudden derailments to cul de sac resonance quality in bits of conversations specifically at narrative tasks katt{ei<~ }(i), katt{e<~}(i), t{a~.u~<}(-r)t((e, tar{u~<}(u){ty}(tt){a~nA~}(e verbal recall attempts t{a~.u~<}(-r)t((e and conversational repairs {figure 8, 10) .

E.g. s :taru{ty}(tt){a~nA~}(e),ka{tt>}(tt){I>~}(i)
tar{u~<}(u){ty}(tt){a~nA~}(e),t{A~}(a)ru{t}(tt)((e-,katt{ei<~ }(i),katt{e<~}(i),t{a~.u~<}(-r)t((e
for: *katti taruttAne*

For example, at conversational repair is seen an utterance with Cul De Sac resonance and high pitched voice in *yee~nu mee~ku yee~nuuu*.. A similar cul de sac resonance at verbal recall attempts and self repair is seen in Apsn D0 with high pitched strained voice in preliminary study by same author (Gayathri 2016)

Figure 8.b. Apsn D0 also showed hyper nasal cul de sac resonance and ~ DZn at his conversational repair

e.g. Cited below is target word dONi in verbal recall attempts of word *dONi* in D0(Accumulation of data from preliminary study Gayathri , 2016). 6 out of 9 attempts show vocalic ~s in verbal recall at narration within conversations . At these moments, his speech sounded different with abnormal high pitched strained cul de sac resonance compared to his basal speech quality at conversations.

{w}(d){u<O>~}(O){n}(N)i
{t<d}(d){u<O}(O){n}(N)I
{t<d}(d){u<O}(O){n}(N){i~}(i)
{t<d}(d){u<O>}(O){n}(N){i~}(i)
{t<d}(d){u<O~>}(O){n}(N){i~}(i)
{t}(d)O{rn}(N){a}(i)
d{u<O~}(O){n}(N){a}(i)
Q
d{u<O}(O){nn}(N){a}(i)
{t<d}(d){u<oo~}(O){nn}(N){a}(i)

11.2.1. Aspsnno1D1 Ambiguities prevail in this category of SNHL, spsnD1. The only residual vowel defect in one Aspsnno1 in D1 is vowel nasalization. With zero vowel shifts in him, his residual defect contains only similar Substitutions(Sn). Further, in contrast, another Aspsnno2D1 has minimal occurrences of NZn. Thus, these two contrastive examples in spsnD1 hinder any general statement of sub group AspsnD1, but idiosyncratic conclusions are made. This is also because unlike psnD1 above, these participants are in different phases of NO – HMO(nasal oral- homorganic) cluster articulation acquisition.

AspsnD1no1 shows three patterns of NO - HMO clusters in his lexicons **.1**. Accurate articulations of NO- HMO clusters samples with zero nasal conditioning of adjacent vowels tingaLu, *tappiskoNDU, kampAssu, frEND, eekanta, iddidrinda, ondu* **2.***Transposed nasalization of vowels* e.g. *sa~{pp}(mp)ige*. But he has similar utterances in which nasal NO clusters are not accomplished as in *sa~{pp}(mp)ige, ye~{T}(NT)Uwa~re, hannerAdg{A~}(A){T}(NT)e , hannO~{d}(nd)UwarE*, and in NO- HMO, HTO cluster context *cA~{tr}(ndr)a* . It appears from examples in second set of lexicons that loss of nasal consonant in succeeding NO- HMO clusters is compensated by transfer of nasalization to immediately preceding vowel. **3**. There are also instances wherein NO- HMO clusters are substituted for oral segments such as [pp]. *m{a~}(a){nd}(d)uwe , b(a~)(a)(nd)(d)alu* From this misarticulated oral [d] > [nd] arises a lexicon with interstitial vowel between two nasal segments, instead of one adjacent nasal segment and vowel~ of [a] occurs in the first example . But in second example vowel NZn is seen in vowel adjacent to newly created NO- HMO cluster. Another such example includes *s{ie<}(i){mp}(mh)A~* . A carry over vowel nasalization can be seen after substituted NO- HMO [mp] for [mh] leading to A > A~. Thus, interaction of NO- HMO clusters with vocalic in conversational profiles of D1 speakers is a complex issue. **4.** Similar transposed vowel NZn is seen at nasal consonant deletion in lexicons e.g. *{n-} {O~>} (O) {D<d} (Dd)a* . **5.** His speech quality is hyper nasal with occasional cul de sac resonance perceived. **6.** There are few examples in his inventory which indicate vowel ~ in purely oral contexts too *ka~wa~{l}(D)e~* which had perceptually high degree of cul de sac hyper nasal quality **7.** His three examples of NO-HTO clusters with nasal consonants has no influence on vowel ~. But e.g., *mahA~{m}(tm)A* indicate NZn. **8.** Geminate nasal clusters [mm][nn][NN] did not trigger vowel~ . An extreme example is with the absence of NZn in this participant in a misarticulated lexicon *inno{nn}(nd)u*, even though [o] is in between two nasal segments; it was not NZd . **9.** He has hyper nasal speech quality with occasional Cul De Sac hyper resonances.

11.2.2. Aspsnno2D1

Aspsnno2D1 has very few examples of vocalic ~ in her fluent speech in conversation **.** **1.** Only rare vowel ~examples are identified **2**. She has not acquired NO HMO clusters; they were substituted by corresponding oral consonant or oral geminate e.g. *sa{p}(mp)ige, sA{w}(m)a{tt<}(nt)igE*. However, only one sample of ND cluster in her conversation did not show vowel NZn *tek{u<O}(O)NDu* **3**.An example of transposed NZn is also identified like in Aspsnno1D1 *sek{A~}(A){D}(ND*). **4.** Her few NO- HTO cluster bearing lexicons did not trigger vowel NZn **5.** Her speech quality was hypo nasal in nature with no cul de sac resonance. **6**. She also exhibited a stretch of utterance with many nasal segments :*nOnONA,nOnONA , nInu, minONA, mEne minONA* . Yet, her vowels remained normal**. 7.** In addition she has consistent denasalized homorganic clusters in her inventory *ba{d}(nd) sa{p}(mp)ige, sA{w}(m)a{tt<}(nt)igE. tu{b}(mb)a na{g}(ng)e* . **8.** Two verbal recall attempts did not cause hyper speech nasality unlike in ApsnD1 **9.** Her speech is of hypo nasal quality

11.2.3. Aspsnsib2 is a second congenital SNHL sibling in his family who has limited language development than in Asp no1 and Asp no2, **1**. He shows vowel ~ more often in nasal consonant context in lexicons, but also their absence in these contexts e.g. *myaeae{L}(D)A~m* **2.** Nasal geminate clusters in lexicons did not condition nasalization *nInn{A>}(a)du, anner{A}(a)Du*. A contrary example seen is .in *{A}(a)nn{A~}(a)* **3.** NO –HMO nasal cluster context *bandi{Law}(lw)A , k{ae}(e)mpu* did not influence ~ , but in example *baeaenk{i~e<}(i)* can be seen DZn NZn . This particular lexical example which has recurred in his inventory is perceived with high degree of vowel NZn associated with Cul De Sac hyper nasal resonance. In addition he also has oral consonant substitution or oral geminate substitution to NO-HMO clusters *{ʔ}(han){O}(o){d}(nd)u, (n-)a{dd>}(nd)e* wherein vocalic NZns are absent . He has additional NO- HMO substitutions for oral consonant in his inventory unlike in Aspsnno1 and Apsnno2 above .e .g. : *m{A~}(A){nt}(t)u, {n<g}(g){u<O}(o){nt}(tt)i{l<L}(ll)a,* which did not always induce adjacent vowel nasalization . **4.** Contrasting examples of same target word is seen as *g{u<o}(o)tt{ie}(i){L<ll}(ll)a. g{u<o}(O)ti{L<l}(ll)a, g{u<O>}(o)tti{L<ll}(ll)A, g{u<O>}(o){nt}(tt)i{L<ll}(ll)A*. Hence , his inventory is complex with correctly articulated NO- HMO cluster , oral consonant substituted for NO- HMO lexicon , and additional NO HMO clusters substitutions for other consonant in his inventory with variabilities of vowel ~occurrence and a transposed sample of vowel ~ in this NO- HMO context is also identified *ba~{d}(nd)*e. But this same lexical sample is articulated accurately in other occasions. Thus, interaction of NO- HMO clusters with vocalics in Apsnsib2 is a variable with multiple patterns of HMO acquisitions like in Aspsnno1 . **5**. In few NO-HTO clusters that he has acquired have no influences on vocalic NZn. He shows absence of vowel NZn at NO-HTO cluster simplification *{m}(b){u<O}(O){Nav}(rnv)ITA* . **6.** A tri -cluster example with NO consonants shows no NZn of vowels *ca{ndAr}(ndr)a*.. . **7.** Interstitial vowels in between two nasal consonant segments influenced definite vowel nasalization *ma~ndyAna , summa~ne* **8.** His speech quality is hyper nasal with cul de ac hyper nasal resonance .Highest bursts of hyper nasality

are seen in some lexicons such as *s{ie<}(i){mp}(mh)[A~}(a)* , *ma~ndyAna*, *baeaenk{i~e<}(i)* **9** Phonetic complexity of vocalic NZn ranged from simple to highly complex like in APsnD1 . **10** He shows high degree of variability of uttering same lexicons than Apsnno1D1 and hypo nasal Aspsnno2D2 , thus adding to difficulties in interpretations of his NZn of vowels.

11.2.4. General inferences on AspsnD1 In general, vocalic nasalization is triggered by multiple nasal consonant segments in lexicons and is hence complicated. There is a beginning trend for definite nasal segment conditioning on vocalics unlike in psnD1 While there are lexical tokens referring to their consistencies a few ambiguities, negating them are also observed. Further, nasal consonant and cluster acquisition are in multiple and different stages. Particularly are the NO –HMO clusters causing their diverse idiosyncratic ~ influences in this group. While two participants demonstrated, considerable occurrence of vocalic NZn Aspsnno2 has sporadic occurrences in her large inventory. But, more than geminate clusters or nasal consonants, the NO - HMO clusters played influencing role in vocalic ~ in this group . Hyper nasality of their speech is a range from hypo nasal to Cul De Sac hyper nasal quality. Transposed vowel nasalizations surfaced in all three participants. No vowel specificity for ~ in general can be inferred.

11.3.msD1 This moderate severe SNHL group has two participants of child and adult type .Given below are their vowel ~ characteristics in lexical contexts

11.3.1 AmsD1: in contrast to PsnD1 and Aspsnno1D1 (11.2), Amssn show very few ambiguities with respect to ~ in lexical contexts .Most of his vowel nasalizations are conditioned only by certain specific nasal segment environments with sporadic exceptions. But, these influences to be discussed in following lines did not happen 100% of the time. In some similar contexts however, the vowels remained non nasal and normal . **1.** AmsD1 has acquired few NO- HMO clusters .Or else, his NO- HMO clusters more organized and are consistently substituted by oral consonant element of the clusters But they did not condition ~in lexical context. E.g. *nanda{l}(ll)a* ,*ombaiU.u(-r-)* *illA{nd}(ndr)E*, *bandiddaa?*, *ti{nd{}ND)i*, *(g-)aNTe*. He does not show HMO cluster conditioning like in Aspsn (11.2). In misarticulated oral context *ba{d}(nd)illa*, *inmU{-r-}ti{L}(ngL)Aytu*, misarticulated oral nasal context he does not have vowel NZn . In only one example of misarticulated nasal context with element [m], he shows a nasalized vowel. *t(s)a~{m}(mbL)A* . **2.** His sensitive nasal segment environments include [m] [mm]. In accurately articulated segments or in their substitutions to other phonetic segments, or as phonetic elements in misarticulated oral nasal HTO clusters. Unlike Apsn, he has acquired several oral nasal HTO clusters. But when misarticulations occurred with consonant element [m] nasalizations are seen , {t*}(s)u~{m}(mn)E~*, *{t}(s)i>{m}(nm){A~>}(A)*. Exceptions identified are in the e.g. *inmU{-r-*

}ti{L}(ngL)Aytu, {t}(S)AmlA and in tri cluster reduction contexts *{t}(s)ambLA.* **3.** He has zero transposed vowel nasalization unlike in AspsnD1 **4.** His speech is perceived as well projected oral quality. **5**. Complexity of phonetic structure of nasalized vowels is simple in nature

11.3.2.CmsD1: **1.** Like Amsn, in child ms SNHL sensitivity to vowel ~ is in [m] and [mm] contexts. **2.** In addition, her nasalized vowels are to some extent conditioned by [n] consonant also. **3.** She has not completely acquired ON- HMO clusters. But, where they existed they did not condition vowel nasalization except in e.g. *s{i~}(i){mp}(mh)A>;mp/mh* . This behavior is similar to AmsD1.**4.** She has zero transposed vowel nasalization in AspsnD1.**5.** CmsD1 has moderate additional sensitivity to [n] environments in addition to[m] and [mm] with [a] in lexicons .Further vowels i , e ,u also are influenced by nasal consonant environments .Her back DZns are not NZd such as in *Am{u<oo}(E)le n{u<O}(O)Du.* **6**. Her speech has well projected oral quality. **7.** Cmssn shows very few ~ ambiguities in lexical contexts .Most of her vowel nasalizations when they occur are conditioned only by adjacent nasal segment environments. But not all nasal consonant environments triggered adjacent vowel ~. Ambiguities to NZn occurrences are rare in CmsD1 like AmsD1. **8**. Lastly, unlike the adult with similar hearing loss in this group, she has other vocalic NZns in nasal segment environment only. **9.** CmsD1 has moderate additional sensitivity to [n] environments in addition to [m] and [mm] with [a] in lexicons **10.** Further, other vowels i , e , u and rarely diphthongs*(m{ai~>}(ai){t}(s)Ur)* also are influenced by nasal consonant environments .**11.** Her DZns are not NZd e.g. *Am{u<oo}(E)le, n{u<O}(O)Du*, unlike in ApsnD1 and AspsnD1 .**12.** A few V.V hiatus under the influence of nasal consonant environment are NZd. *m{a~}(a)nE~.i(-l)'*.**13.** She also has consonant cluster simplifications with vowel insertions. In these circumstances where nasal consonant [m] existed this vowel is also NZd *{A+}lA{kASA~m}(Sm)i.*

Hence, her major proportions of occurrences of vocalic NZns are in nasal segment lexical contexts. With these additional vocalic nasalizations her phonetic complexity of nasalized vowels are coalesced and more complex than in AmsD1. However, her vocalic NZns are less severe than in ApsnD1. Further, her vowel additions in lexicons are not nasalized. Overall, the incidences of NZns are relatively higher than in AmsD1. Unlike Apsn, she did not have ~ on wide range of vocalics even though they are present in her inventory such as the V.V hiatus , DZn , and vowel additions . Hence, her vocalic ~ inventory is phonetically much simpler than ApsnD1 even though she has relatively limited number of language experience. But, her phonetic complexities of vocalics are more complex than in AmssnD1 whose ~ is only on vowels.

11.3.3. Similarities of vowel NZn behavior within msD1. In this section overall performances in NZn behavior in AmsD1 11.3.1 and CmsD1 11.3.2 is compared. All vowel NZns are coarticulatory impacts of adjacent nasal segment consonant in lexicons. But, nasal consonants did not result in adjacent vowel nasalizations in lexicons 100% of the time They have well projected oral speech quality. Overall, they have only sporadic vowel ~ ambiguities. Both participants are sensitive to [m] and [mm in lexical environments' resulting in a trend for adjacent vowel NZn .No evidence of HM cluster influences and HTO cluster influences are seen in both participants converts to SpsnD1 To that extent, the ambiguity of NZn seen in higher degree of SNHL in D1 gets diminished to a great extent. In addition, (figure 10) . Cul de sac resonance is absent in both participants. However, CmsD1 had more types of vocalic segments influenced by nasal environments and an additional Influence of [n] consonant in lexicons, when compared with AmsD1.Even though a child ,msD1 , shows definite trends for NZn than in ApD1 and AspD1 SNHL types . Thus degree of SNHL is a contributing factor to vocalic ~ behavior in SNHL D1

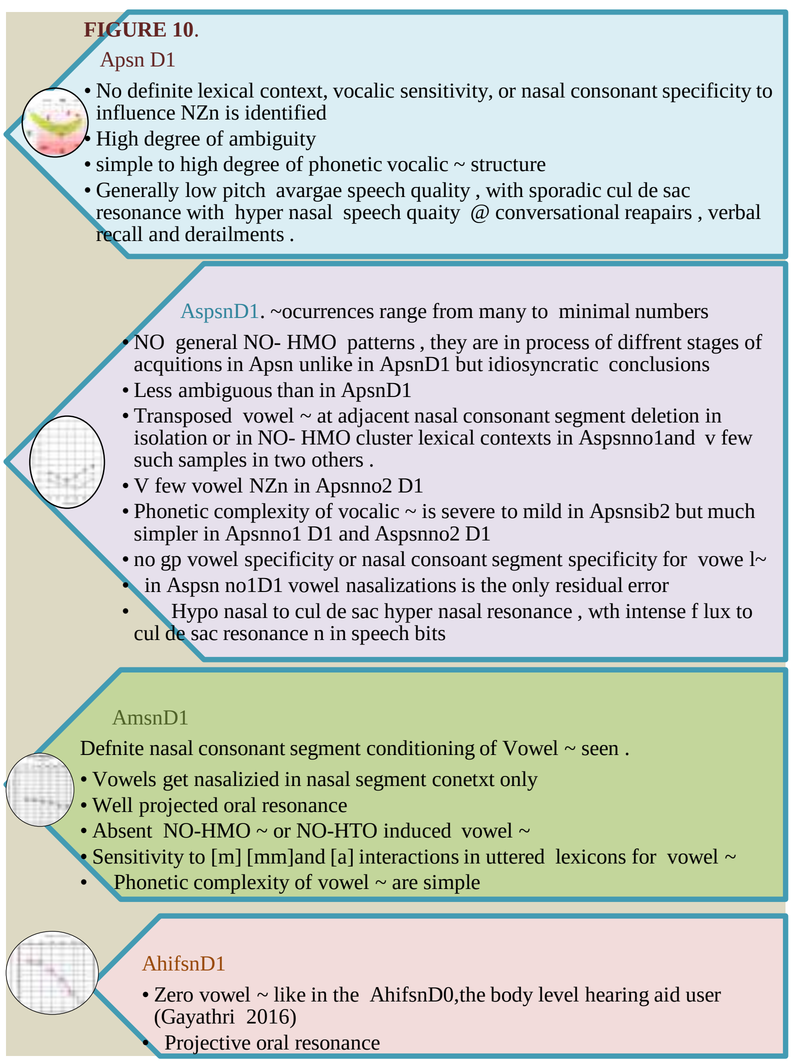


Figure 10. Vocalic or Vowel NZn characteristics in diffrent degree and pattern of SNHL in D1

11.4. AhifSNHL in D1 and also in D0 gp (in preliminary study Gayathri 2016, 1983), have well articulated vowels with zero nasalization in their inventories. Zero vowel NZn, good oral projective speech (fig 9)

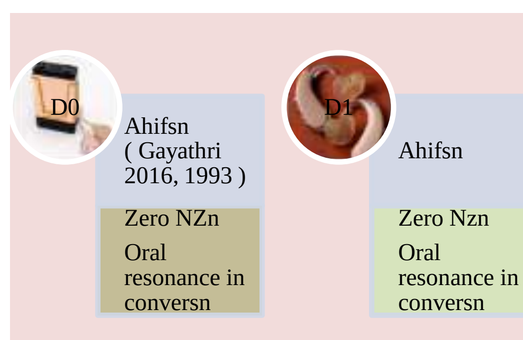


Figure 9. Ahifsn D1 and D0 zero vowel ~ and oral resonance

quality with no Cul De Sac resonance.

Thus, vocalic nasalization is a complex issue in D1. Vocalic nasalization is the impact of integration of many parameters such as segmental phonetic acquisitions which comprise the vowels, nasal consonants and nasal clusters. It is also the consequence of their error segments embedded in their inventories, For example, the diphthongization vocalic in an inventory interacts with adjacent nasal consonant or nasal cluster with outcome of vocalic NZn in the inventory. Vocalic elements of diverse nature in lexicons listed under A in table 2, which interact with diverse nasal segment patterns listed under B in table 2 which comprise the nasal consonant, nasal geminates , NO- HMO clusters, NO -HTO clusters in participant's inventories . The core target segments of Kannada exhibit different phases of acquisitions and defects in their inventories in D1 (fig 5, 6, 7, 9 and table 2).

Yet , idiosyncratic patterns have emerged with few consistent patterns (see table 2 fig 5 and 6) .An integration of target language specific Kannada inventory of vowels with participant specific inventory reveals realistic abundance of NZns and some general and idiosyncratic patterns . Unlike DZns and alternate vowel substitutions analyses of vowel ~ yields only a few general inferences .Some of these are idiosyncratic .Ambiguities for conclusions emerge in large numbers, in vocalic ~ token contexts in lexicons. The vocalic nasalizations are impacts of nasal segments embedded in conversation and the adjacent vocalics in lexicons (figure 5 and 6, 7). Their idiosyncratic ambiguities diminish from highest degree in APsnD1 to lesser ambiguity in AspsnD1, to definite NZn in AmsnD1 as discussed in later sections 11 of this paper. Thus, severity of SNHL is a major parameter in influencing vocalic NZn. Phonetic complexities also vary as denoted under section 11 and figure 8, 9, 10 and 12 with severity of hearing loss. A definite conditioning by nasal consonant segment over vocalics emerges only in moderate severe congenital SNHL in lexicons. This regularity is also seen in CmssnD1. This early pattern in child mssnD1 is in striking contrast with adult participants ApsnD1 and AspsnD1 in general. These consistent results of vocalic ~ in mssnD1 are indicative of coarticulatory effects of adjacent nasal segment in the same lexicon . In ApsnD1 no such conclusions can be made due to the distributions of vocalic ~s in all four cells of 'hit and miss matrix'. On the other hand, while a major proportion of idiosyncratic vocalic ~s in AspsnD1 is contingent in at least some nasal segment environments presented above , the stability of oralized vowels in nasal segment context in this group is specifically not completely generalized. Both adult and child msD1 show oral speech quality ,in addition to consistent vowel ~s in nasal segment contexts only . Otherwise, the vowels have remained oral in these lexical contexts . The descending cascading patterns from p, sp, to ms indicate definite role of auditory feedback in vocalic ~ performances in D1 .Diverse idiosyncratic vowel ~s are common in AspsnD1 .

Other factors for perceived nasality included, some lexical contexts perceived as severe hyper nasal than other lexical contexts in some participants. In contrast, all stressed word tokens shows absence of vocalic NZn. All these parameters are bound to contribute to intricate variability of vocalic NZn in D1.

D2 group

Two of three adult congenital SNHL D2 speakers present vowel~. no1 D2 speaker has atypical conversations with *intermittent stretches of utterances* which comprised random vowel errors of both similar and dissimilar vowel substitution types along with normal vowel articulations. No definite nasal consonant environmental conditioning is identified like in ApsnD1 speaker. But it was synchronous also with hyper nasal cul de sac resonance in these speech bits .Sporadic on and off stretches of alternating cluster of speech characteristics are atypical of congenital SNHL speech. He presents variability in vowel articulations at recurrent alternating *sporadic stretches of utterances* in conversation along with resonance changes. This comprised remote muffled, squeaky voice, high pitched, nasal , tense rigid, relatively minimal jaw movements and horizontally back -focus of voice quality. Perceptually, these typical speech bits implied overall *Cul De Sac Hyper Nasal Resonance* with probable conjecture of retracted tongue through his voice quality and relatively limited jaw excursions and rigid facial posture in these speech bits . These synchronized clusters of speech deviancies of speech get nullified or zeroed down in alternate normal speech bits .This is definitely an atypical characteristic not reported in literature of congenital SNHL. Otherwise, rest of his other bits of his conversation is normal. Occurrences of similar vocalic substitutions are in relatively large proportion of occurrences compared to a few dissimilar vocalic substitutions in his Cul De Sac speech bits.

His affected stretch of speech bits comprised of both similar and dissimilar substitutions only at affected alternating speech – bits. Both of these are affected with nasalization of vowels (see examples and figure 10). The attribution of vowel NZn in D2 speaker is on pure vowels of either the target types or substituted vowels unlike the broad vocalic NZns found in D1 speaker.

Table 4 Examples of V ~ in atypical episodes of utterances in a D2 speaker

yA:k{ʌ~<}(E)ndre
h{ƆƆ~<}(O)gbOdu
En{ʌ~}(a)nta
Ad {ɒ ~<}(a)kke
{O~}dt{i~<}(i)rtIn{a~}(a)lla
K{U~<}(U)DA
maney{a~}(a)lli~rbEkAdr{E~}(E)
y{A~<}(A)km{A~}(A)DbArdU?
h{O~}(O)gttidrE

1. Nasalization of normally articulated vowels in affected speech bits. e.g. *maney{a~}(a)lli~rbEkAdr{E~}(E), y{A~<}(A)km{A~}(A)DbArdU?, h{O~}(O)gttidrE.*
2. Nasalization of substituted vowels e.g. *yAk{ʌ~<}(E)ndre, h{ƆƆ<~}(O)gbOdu, En{ʌ~}(a)nta , Ad {ɒ <~}(a)kke*

What is evident in these atypical speech- bits is that normally articulated and normally resonated speech turns into erred phonetic segments and abnormal cul de sac resonance in the same participant. Now, the question is whether the rigid cul de sac resonance speech mechanism configuration with possible retracted tongue conjectured in atypical speech bits, in this participant is imposing vowel segment nasalization discussed above. The synchronous transformation (figure 11) to normal speech in alternate bits of utterances leads to this speculation. An objective study with instrumentation approach integrated with perceptual study is warranted for these vowel ~ patterns in D2 no2 and D2 no1 and D3 below .

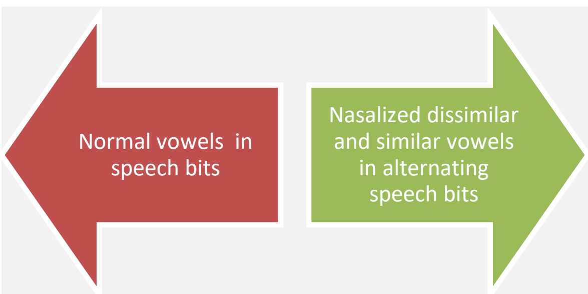


Figure 11.Alternating dual speech bits with NZd and normal vowels; normal average to cul de sac speech quality in an atypical D2 speaker

Another D2 speaker shows sudden vowel ~ in conversation. *Naa~nu~ kAlEjgO~gbEKu , madwE~gbannI, IgtAnEbA~sshO~ytu* is a sporadic hyper nasal speech with similar vowel nasalization substitutions in this utterance . His hyper nasal speech quality is not Cul De Sac hyper nasal resonance. Otherwise, his speech is normal at conversations. Last D3 speaker does not have vowel nasalizations, hyper nasality or Cul De Sac Resonance . The attribution of vowel NZn in D2 speaker is on pure vowels of the target types.

D3 Group

D3 as a group have no perceived vowel ~ in general. But, sporadic vowel ~ utterances in two D3 out of six ,exhibited nasalized vowel utterance in one D3 speaker e.g. : *b{a~}(a)nni, oL{A~}(A)ge~. But* , in the second D3 speaker with cul de sac resonance quality *vowel, ~ s not seen e.g : TUbiDONA aStE . meelidaare ,bassalhOgbartIniii,yaawudAdrU sArii, nAnu skuLbAg tAnde , mADkoDIniWu* . They are however, superior to CmssnD1 and AmssnD1 with minimal nasalization occurrences. (See figure 10). The attribution of vowel NZn in D3 speaker is also on pure vowels of the target types with absence of other vocalics in their transcribed inventories.

Comparison of ~ occurrences in D1, D2 and D3 Throughout the parent study three hearing devices are compared for vowels errors. In current study ~ of vowels across three groups D1, D2 and D3 are compared. (Figure 9, 10, 11, and 12).

2.1 All D1 participants except AhifsnD1, showed vowel or vocalic nasalizations. Similarly, AhifsnD0, with body level hearing aid had no nasalization in previous studies (Gayathri 2016, 1983).

2.2 One participant Aspsn no2D2 has atypical vowel nasalization synchronous with hyper nasal Cul De Sac Resonance has sudden alternating speech bursts with ~ of vowels.

2.3 .Absence of nasalized vowels , hyper nasality , and cul de sac resonance are characteristics only of AhifsnD1 in contrast to groups D2 , D3 as and other participants in D1 group.

2.4.Four out of six D3 participants have normal speech .but two others show sporadic hyper nasal utterances with either occurrences of associated vowel~ or with their absences .

Figure 12 Vowel nasalization patterns (~) in conversational lexicons of D1, D2 and D3 speakers

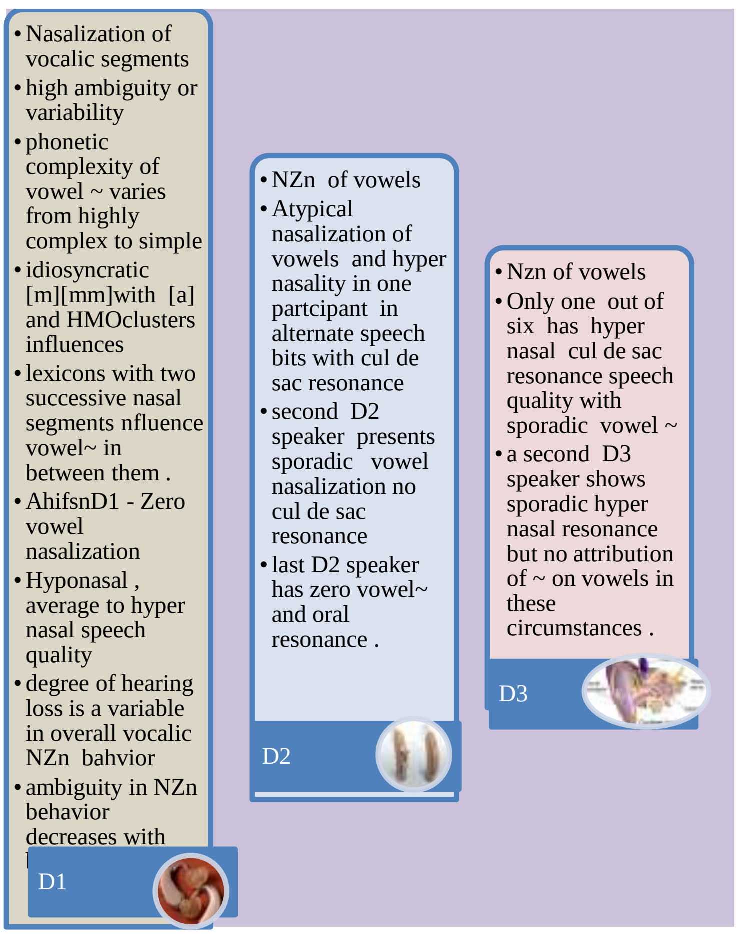


Table 5 Distribution of Resonance patterns in speech in D1, D2 and D3 speakers

	Hypo nasal	*Oral*	*Hyper nasal*	*Over all hyper nasal cul de sac Resonance*	*Sporadic*
D1					
AP		*1*			*1,Flux to Cul de sa c Hyper nasal*
Asp	*1*		*2*	*2*	
Ams		*2*			
Ahif		*1*			
D2		*2*	*2*		*1, Alternating Cul de sa c Hyper nasal*
D3		*4*			*2 ,Cul de sa c Hyper nasal*

12. Speech quality patterns of speech From the audio recorded data judgments are made regarding general nature of speech quality . As no separate voice assessments are made the term speech quality is used in current study .Perceptual judgments of conversation in the speech quality perspective again are diverse and heterogeneous in three hearing domains D1,D2 and D3. Perceptual judgments on nature of speech quality are not made in CpsnD1 and Apsnsib2D1 due to limited speech corpus in these two participants . AhifsnD1, two mssnD1, four CI participants and two D2 participants in current study did not show abnormal resonance patterns. Preliminary research evidences (Gayathri 2016, 1983) have also showed normal speech quality in AhifsnD0 (D0=Analogue body level hearing aid user). Both AmssnD1 and CmssnD1 show normal speech quality with good projection of speech at conversations, with no evidences of Cul De Sac resonance. In others , overall resonance quality in speech varies in a wide range from hypo nasal to hyper nasal with or without Cul De Sac resonance (table 5).Sporadic episodes of hyper nasal Cul De Sac resonance are also observed in Apsn D1 (11.1) and two D3speakers with average oral resonance. Recurring alternating hyper nasal Cul De Sac resonance is seen in one atypical D2 Aspsn speaker. One other AspsnD2 speaker has average speech quality . Last D2 speaker showed episodic bursts of hyper nasal speech quality with NZd vowels. . AspsnD1 shows hypo nasal speech quality in one participant and hyper nasal Cul De Sac resonance in two other Aspsn D1 participants . Thus, speech quality is a diverse or heterogeneous phenomenon in congenital SNHL participants in current study.

12.1. Speech resonance quality and nasalized vowel association patterns Inferences in this directions indicates general absence of direct and definite relationship of vowel NZn occurrence performances with perceptual judgments' of resonance in current study . Following inferences are drawn regarding these processes.

12.1.1. In all three groups D1, D2 D3 and hyper nasal segmental vowels occur in the dynamics of natural conversations not always concurrent with hyper nasal speech quality .

12.1.2. AmssnD1 has a steady oral projective resonance but moderate vowel nasalizations are seen with absence of associated hyper nasal Cul De Sac Resonance.

12.1.3. Apsn D1 has oral speech quality with episodic flux to Cul De Sac Resonance in speech. He has NZd vocalic segments in his speech corpus These occur at verbal recalls or conversational repair..

12.1.4. In Aspsnno2D1, is found overall hypo nasal speech quality This did not mean absence of vocalic nasalization.

12.1.5. In Aspsnno1D1 and Aspsnsib2D1is found overall hyper nasal speech quality with hyper nasal cul de sac resonant type speech quality and vowel or vocalic nasalizations.

12.1.6. Two D3 speakers demonstrated normal speech quality with minimal flux to cul de sac resonance with associated hyper nasal vocalic segments in their speech corpus.

12.1.6. Zero vocalic nasalizations, and normal speech quality is seen in AhifsnD1, four D3 speakers and one D2 speaker only . The best performance with respect to speech quality combined with zero ~ behavior is seen only in AhisfsnD1 or D0.

12.1.7. Every vowel in Cul De Sac speech quality is not nasalized in D1 , D2 and D3 e.g. *yee~nu mee~ku yee~nuu D1; and En{ʌ~}(a)nta , Ad {ɒ <~}(a)kke in D2.*

12.1.8. Atypical alternating recurrence of speech bits with Cul De Sac Resonance is contrastingly different from the other type of speech bits in a D2 speaker. While the former contained nasalized vowels and dissimilar substitutions, the latter did not include them .This unique pattern is not reported in hearing impaired speech literature. These findings in a D2 also hypothesize the possible association of Cul De Sac Resonance with vowel ~ in speech .

12.1.9. Cul de sac resonance gets episodic at conversational repair in ApsnD1. This also happens at his attempts to verbal recall and communication breakdown 12.1. 10 none of the vowels in stressed lexical samples shows nasalized vowels in hyper nasal segment context .they appears to be relatively loud and oral or even elongated in duration in D1

12.1.10. D3 shows cul de sac resonance in two participants only . One D3 speaker of two has no perceptual attributed NZn of vowels in spite of Cul De Sac resonance.

The vivid behaviors and idiosyncratic association of vocalic nasalization behavior to overall resonance pattern is thus obvious. Clause 12.1.7 holds its significance in speech sampling methodology in study of vowel nasalization .it indicates need for multi syllabic and multiple speech samplings in future.

That resonance is not always a steady behavior is also evident in 12.1.9 .Better auditory acoustic access emerges in clause 12.1.6 is to be compared with other D1 speakers. Lastly, lexical stress lacks hyper nasal resonance in D1 speakers 12.1. 10. Miscellaneous results with respect to speech resonance are seen in ApsnD1 from hypo nasal extreme to hyper nasal Cul De Sac extreme. One D2 speaker of similar nature of hearing loss shows oral resonance and zero vowel~.

General inferences on speech quality in congenital SNHL .Nasal speech quality is a persistent phenomenon in D1, D2 and D3 groups. A range of speech quality good projective speech , hypo nasal, average and hyper nasal speech qualities are seen in congenital SNHL participants in this study. At least a general inference that D3 as a group is better than D2 and D3 in terms of NZn of vowels can be made, even though two out of four show episodic cul de sac resonance in speech, they did not contain vowel NZns. Normal speech quality with absent vowel NZn is characteristic of AhifsnD1, four D3 speakers, and one D2 speaker. Compared to D1, D2 and D3 groups, in general are better in terms of zero perceptually identified coarticulatory vowel NZns. Vocalic coarticulatory NZns are typical of only D1 speakers. In D2 group and D3 group non coarticulatory NZns are on pure vowels only. Ahifsn in both D1 and D0 (from results of previous paper Gayathri 2016) show normal speech quality and zero vocalic NZns.

Other idiosyncratic speech patterns. D2 as a group has heterogeneous results. Speech of one D2 participant has an atypical alternating; recurring hyper nasal cul de sac resonance with non coarticulatory vowel NZns, The next participant has hyper nasal resonance with non coarticulatory vowel NZns. Last participant has normal speech.

D1 group also shows idiosyncratic coarticulatory NZn and speech quality behaviors .average speech quality with random vocalic NZns are typical of profound SN hearing loss in D1. Aspsn show both hypo nasal and Cul De Sac Hyper Nasal Resonance speech quality. Both adult and a child MssnD1 on the other had show normal speech quality. A definite coarticulatory vowel NZn with mainly [m]and [mm] in lexicons are seen in mssnD1. In two Cul De Sac hyper nasal AspsnD1, while frequent nasal consonant, NO- HMO cluster and NO HTO cluster coarticulatory influences are seen, there are also few NZd vowels with zero nasal consonant environments. Hypo nasal AspsnD1 on the other hand is not totally devoid of vocalic NZns. She shows rare NZns in her fluent conversation corpus .

Speech quality is not a steady feature Multiple speech samplings though natural conversation in current study facilitates additional finding on nasalance in congenital SNHL. It is also highlighted that speech quality is not a steady feature in many congenital SNHL leaving aside the unique atypical D2 speaker**. 1.** In some participants sudden bursts of hyper nasal quality is seen in speech like in two D3 and a D2 speaker with absent coarticulatory vowel NZns **2.** A sudden flux to Cul De Sac hyper nasal speech quality from average speech quality is seen in an ApsnD1 speaker. This occurred at his conversational repairs and vocabulary recalls. **3.** Some lexical contexts of vocalic NZns are perceived with greater hyper nasal speech quality than rest of the conversation as seen in 11.2.3.8 *s{ie<}(i){mp}(mh)[A~}(a) , ma~ndyAna, baeaenk{i~e<}(i* in an AspsnD1 speaker .**4.** An atypical recurring alternating speech bit patterns with synchronous Cul De Sac hyper nasal speech quality associated with vowel nasalizations is found in D2 group 12.1.8 .

Discussion

In Kannada, all ten vowels are oral vowels. But, vocalic or vowel nasalization is a predominant phenomenon even after completion of long term speech and language therapy specifically in D1 users. They present high variability in their occurrences as residual errors. Hence, the current study aimed at identifying organized patters of vowel NZns in dynamics of natural conversation speech corpus with availability of multiple vowels ~ tokens. Unlike, the DZn and dissimilar substitutions analyzed in previous research, vocalic nasalization is a persistent phenomenon in each of three contemporary hearing aid users D1, D2 and D3 in general (Gayathri vowel I 2019). An integration of preliminary study adds to this finding that they are present in abundance also in conversation of D0 speaker (Gayathri 2016).

In the current study, analyses of conversational corpus are undertaken from two main stands. They comprise the perspective of perceptually identified vocalic segmental ~ based on the concept that speech organization is basically segmental and that their gestures are sequential (Berti 1979 , 1990) and from overall nasal resonance parameters evaluated in the present study in the context of conversational sampling . First dimension is the coarticulatory effect on vowels or the conditioning of nasalization of vowel in lexicons by adjacent nasal consonant segment in same lexicons. The second is the perspective of perceptually judged resonance quality in speech as either hypo nasal, average, hyper nasal and Cul De Sac resonance. They are compared across different hearing domains D1, D2 and D3. These were compared with degree and pattern of hearing loss in group D1 and different hearing device users. The speech corpora driven analyses has led to further inferences in lexical stress and vocalic nasalization encountered in group D1. All these results are discussed under r the following sub headings.

1. **Occurrence of vocalic NZn in D1, D2 and D3.** is across all hearing domains D1, D2 and D3. This is in agreement with Boone (1976), Bell (1910), Numbers (1936), Baudonck, Lierde, Dhooge& Corthals (2011); Gayathri (2016); Osberger's (1980) studies . Recent report by Paatsch , Blamey & Sarant (2001), indicates vowel nasalization in both D2 and D3 speakers in

different degrees . All vocalic segments comprising of similar and dissimilar substitutions (Gayathri 2019, Vowel series II) are nasalized in most D1 and in a D2 speakers. While D3 has only similar nasalized vowels, D2 and D1 also have these vowel~. In general, Ahifsn in D1 and D0(from preliminary study Gayathri 2016) hearing domains , four cochlear implanted in D3 group, and one out of three D2 speakers are exceptions with absent vowel nasalization. Two D3 speakers show sporadic vowel nasalization occurrences. Instead of general findings for the groups, many idiosyncratic observations are inferred. To that, extent vowel ~ presents intra group variability in D1.

Even though, hyper nasality and Cul De Sac resonance are reported as characteristic signs in congenital SNHL literature. This is more so, specifically reported in D0, the body level hearing aid users. That is at the time when analogue body level hearing aid was in vogue (Boone 1976). Kim, Yoon, Kim, Nam, Park & Hong (2012) has illustrated an extensive review on this nasal feature in his paper. In general, Ahifsn in D1 and D0(from preliminary study Gayathri 2016) hearing domains , four cochlear implanted in D3 group, and one out of three D2 speakers are exceptions who show normal overall resonance . D1 users in current study present hypo nasal, average and hypo nasal conversational speech quality. Further, few sporadic fluxes in episodic Cul De Sac resonance are noted in specific communication contexts inApsnD1. Both the adult and child msD1 show average oral resonance in speech quality. A D2 speaker has shown alternating hyper nasal Cul De Sac resonance in conversation speech bits and associated nasalized vowel segments. Two D3 speakers on the other hand show sporadic hyper nasal resonance with no nasalized vocalic segmental associations.

2. **Occurrences of vocalic NZn in D1**. Congenital SNHL D1 has a varied vowel inventory in its participants. They range from collapsed anterior and posterior inventory(Gayathri vowel series IV 2019) , vowel shifts, with dissimilar and similar vocalic substitutions and different phases of nasal segment acquisition which comprise single nasal consonant, nasal oral clusters of homorganic (HMO) and nasal oral heterorganic (HTO) types in the dynamics of their connected speech production processes . .Hence, the understanding of vocalic nasalization’s in this group D1, is in the context of their segmental acquisitions in conversation and the errors are rather labeled as vocalic errors with a broader perspective than vowel errors Lexicons are explored for nasal segment conditioning of vocalics embedded in conversational data bases in respective participant inventory. It is expected that nasal segment environment in lexicons induce nasality in vocalic of D1.This showed highly ambiguous organization from consistent nasal to less

ambiguous organizations embedded in participants ‘ inventories in D1 group . Zero vowel nasal conditioning in lexicons is seen only in Ahifsn under D1 illustrated in figs 5, 6, 7,8,9,10,12 and table 2. All these are discussed in the following paragraphs

3. **Idiosyncratic lexical vowel ~ patterns are exclusive to D1group**. Adult and child moderate severe SNHL show tendencies for nasalization in the context of nasal segment[m][mm] with vowel [a,A] . Other than these, homorganic nasal clusters show higher influences on vocalic nasalization in general in the spsnD1 types who show different stages of acquisitions of HMO clusters. Consonant cluster simplifications with insertion of vowels are also sometimes attributed with nasalized quality.. It can be thus concluded that this group of hearing aid usersD1, have general difficulty in functional timing and monitoring of velo -pharyngeal valve for effective oralized vowels and vocalics in nasal segment contexts on lexicons in their Kannada inventory. In addition , in CnVCn contexts wherein Cn is nasal segment in lexicon with medial vowel , vowel gets nasalized in some D1 speakers . Unlike severe to moderate degree ambiguities of vowel ~ seen in ApsnD1 and AspsnD1 the mssnD1 types on the other hand, shows definite nasalization of vowels in only nasal segment contexts in lexicons. Idiosyncratic lexical phonetic grounding to surface phonetic vocalic nasalization or its absence in conversation speech framework is thus inferred (Table 2 and figures 5, 6, 7). Tokens of vowel nasalization are idiosyncratic impacts of interaction of A and B listed in table 2(figure 5,6 ,7) both of which are embedded in the inventories of participants in D1 .

4. Consistent absence of vowel ~ in stressed word utterances in D1. There are consistent and complete absences of nasalization of vowels in the context of stressed lexicon samples in word *tumba* (large amount) in affected D1 participants. Sign or gestures , such as exaggerated widened eyes, high intra oral pressure at [mb] utterance with puffed cheeks , long duration of NO- HMO cluster words and increase in loudness in some with associated hand gestures indicate largeness in some are associated with lexical stress . Ohala & Ohala ‘s (1993) views that buccal obstruent’s need velar closure is partially supported in these high intra oral pressure stressed words contexts with [mb]. It can also be inferred from their studies and these examples that a tight velar valvular closure is necessary velar condition at articulation of stressed words ..

5. **Aspsnno2 with hypo nasal speech quality** has sporadic vowel ~ s only in her fluent abundant conversation sample. Only Aspsnno2D1 has hypo nasal speech quality which could be attributed

to disturbed proportions of NO- HMO clusters in her fluent speech with sporadic nasalized vowels. Even heavily loaded nasal segment occurrences are not nasalized in her speech e.g.: *nOnONA,nOnONA* , *nInu*, *minONA*, *mEne minONA* . In addition , as mentioned above, she had consistent denasalized nasal consonants and homorganic clusters in her inventory *{b}(m)artooytu, ba{d}(nde,) sa{p}(mp)ige, sA{w}(m)a{tt<}(nt)igE. tu{b}(mb)a na{g}(ng)(see Table 4)* . Her hypo nasal speech quality, could be due to this combined impact of these segmental behaviors in running conversation, and lack of hyper nasal cul de sac resonance quality. This is perceived in spite of sporadic nasal segments in her lexicon. No flux to hyper nasal speech is noted in this participant unlike in 6. The results in this participant points forward to the plausible fact that overall perception of resonance of speech quality in natural speech outcomes is a complex of interactions and balance of existing inventories of vowel – nasal segments.

6. **Cul De Sac hyper nasal resonance at communication breakdown in ApsnD1**

ApsnD1 shows Cul De Sac resonance with high pitch and hyper nasality at his conversational repair or vocabulary recall e.g.: *yee~nu mee~ku yee~nuuu.* .Otherwise his speech shows average resonance with low pitch with no hyper nasality in spite of nasalized vocalic segment occurrences in his conversation. Thus, overall basal speech quality fluctuates when unexpected additional demands divert the speech production process in this participant.

7. **Some segmental and speech quality paradoxes identified in current study.** From current study and the discussions above, some paradoxes on vowel **NZns** have surfaced in D1 and D2.

First paradox,, is the occurrence of **vowel NZn to a sporadic extent in hypo nasal Aspsnno2D1** participant, see clause 12.1.4. .This negates the direct relationship of vowel ~ to resonance of speech quality. Similar contradictory evidence can be seen in Amssn and Cmssn with nasal vowel tokens embedded in their conversation but oral well projected resonant speech quality.

Second paradox, is the **irregularity of degree of perceived nasalization in specific segmental – lexical contexts, indicating that nasal speech quality is not steady in nature .** A sudden fluctuation in perceived nasality is encountered in a few contexts such as in few lexical segments or even in participant's conversational status A relatively high degree of nasalance is found in *baeaenki~e<, baeaenki~e<, si{mp}(mh){A~}(A) , ma~ngge, E~mmE* than *_si~mpA>* or rest of the conversation in this same participant Apsnsib2D1 .Similarly, prolonged diphthongization coalesced with nasalization seen ApsnD1 appears to be perceptually highly nasal conspicuous speech -stretch e.g.: *g{u<O>~}(O){t}(tt)i{l}(ll)a*. A similar context is noted in preliminary paper (Gayathri 2016)with analogue body level hearing aid user , D0 e.g. : *{t<d}(d){u<O~>}(O){n}(N){i~}(i)*. Thus, degree of NZn in some lexical contexts drastically varies from overall degree of NZn in D1 . Some conversational repair contexts, attempts for verbal recall and conversational breakdowns are also the causes for increase in degree of nasalization of speech bits, specifically in ApsnD1. E.g. at this highly NZd speech bit in the same participant, *yee~nu mee~ku yee~nuuu* is a breakdown of conversation, wherein the question asked by the interviewer is not comprehended after repetitions of the question. Associated with this breakdown is the high pitched strained pharyngeal voice and Cul De Sac resonance onset in his regular low pitched normal speech quality. It must also be observed that at hyper nasal Cul Des Sac resonance speech bits not all vowels in them are NZd .Thus speech quality with respect to NZn is not a steady feature.

Last paradox in D1, is the evidences of transposed vowel ~ which appear as though they are complementary vowel nasalization at the omission of adjacent nasal consonant or nasal consonant element in cluster if the example is considered , in AspsnD1no1 for example *(n-)){I~}(i)ru, ba~{d}(nd)e* . Even though they [I~][a~]surface as complementary nasalization embedded in lexicons in conversational speech, they logically appear to be a controversial finding in the context of ambiguity of nasalization occurrences in Aspsnno1D1 mentioned above. It is speculated if these are outcomes of partial audible articulations of omitted nasal segment. For example[n] in [nd] of *ba~{d}(nd)e* nasal consonant[n] in *(n-)){I~}(i)ru* or [n-]in [bande] is not articulated effectively to be audible . Specifically in this participant are seen instances or artciulatory movements with inaudibility , for e.g. at [k] articulation in [kAge] resulting in [Age].A time-delay of onset in audibility of this word even though articulatory movements such as mouth opening for [k] had begun is one example for this artciulatory time dysynchrony. With collapse of audibility of lingual – dental contact and possible onset velar lowering must have contributed to {I~} occurrences in first example. Similar explanations hold for occurrence of [a~] in *ba~ {d}(nd)e*. These arguments are proposed in the context of this participant having exhibited different phases of NO – homorganic cluster acquisitions in his inventory. Second argument is from the evidences of observations of inaudible articulatory movements at data collection in conversation. Lastly is the obvious moderate degree of ambiguity in nasal segment contexts in lexicons, thus implying lack of velar control and monitoring for oral articulation of vowels of Kannada. Hence, it is concluded that the transposed vowel~ are not compensatory NZns in D1.

8. D2 and D3 also display a heterogeneous vowel ~ behavior .While some participants present absolutely no vowel ~ some participants present V~. In spite of improvement in technology in D2 and D3 hearing devices and better auditory accessibility than the D1 group , vowel ~s remain *stubborn* residual vowel errors in some of their conversations . This happens even after completion of long term speech and language therapy in all groups no specific idiosyncratic segmental context associations for V~ like in D1 is identified for both of these groups. In both these groups are evidences of hyper nasality with cul de sac resonances. Phonetic complexity of ~Vs in D2 and D3 are simpler than found in few tokens under D1. Incidences of NZn also with a low end range from being solely sporadic in D2 and D3 speakers. Of significant interest is the finding of atypical D2 speaker with frequent alternating speech bits with nasalized vowels and associated Cul De Sac occurrences .A D2 speaker presents a paradox of speech symptoms in his fluent conversation.

9. **The paradox of alternating speech bits in a D2** speaker with ~ vowel segments and Cul De Sac resonance in no2 D2 speaker shows alternating speech bits with opposing cluster of speech signs .n first type of speech bit he has normal articulation of vowels and normal resonance . In second type of speech bit, he shows hyper nasal cul de sac resonance and vowel substitutions with horizontal pull back of front vowels and pull -down of high back vowel. Either normally articulated vowel or these substituted vowels get nasalized in this second speech bit type. The two types of speech bits keep recurrently alternating .A second referral for ENT specialist and a physician's examination ruled out any organic involvements. These two alternating speech bits with nasalized vowels in one type and normal vowels in other speech bit is another paradox identified in present study, such a pattern is not reported in literature. The combined signs of hyper nasal vowels and hyper nasal substituted vowels with cul de sac hyper nasal resonance and their total disappearances to normalcy in their next speech bit are suggestive of integrated unified vowel articulatory mechanism with mechanisms causing hyper nasal Cul De Sac resonance projecting two speech signs together and also at their disappearances . Probable posture of speech mechanism is contributing to these unified speech and resonance behaviors. It is relevant to recall Shosted's (2012) propositions and experimental findings that acoustic characteristics of nasalization can be attained by motor equivalences, by a family of speech gestures that include, but are not limited to, the opening of the VP port.

10. **Some consistencies to vowel ~ s.** Conversational speech corpora of congenital SNHL after long term comprehensive aural oral speech language therapy (LT-CAOSLT) comprise of normal segmental articulations, and their misarticulations**.** Hence, their vowels comprise of target vowels, substituted vowels and vocalics such as DZn, TZn, V.V hiatus and vowel insertions at consonant cluster simplifications. The nasal consonant segments like other consonant segments encompass single consonants, and different stages of cluster acquisitions. The participant specific realistic speech inventory provides for examinations of various contexts of vocalic interactions with different nasal segment in this current study.

Several idiosyncratic lexical patterns which induce vowel~ are identified. The vowels between interstitial nasal segments in lexicons, nasalizations of vowel [a,A] in only adjacent [m] or geminate [mm] nasal segment contexts yield vocalic or vowel NZns . High nasal consonant loaded utterances did not induce NZn in AspsnD1no2. NO- HMO cluster contexts have induced ~s in some ApsnD1. Hypo nasal speech quality does not mean total absence of NZd vowels as evidenced in Apssnno2D1. Absence of vowel ~ is consistent throughout stressed lexicons in D1 participants with associated loudness and in some high intra oral buccal pressure for [mb] phonetic element sin lexicons *tumba*. Cluster simplifications with vowel insertions get NZd in nasal segment lexical environments. Not every vowel in hyper nasal speech or in hyper nasal cul de sac resonance is affected with vowel ~. But, ~ is distributed in some vowels only. Nasal speech quality is not steady throughout the conversations. While some lexical contexts are perceived with higher degree of NZn than rest of the words in some participants; in some others there is sudden exacerbation of vowel ~s at verbal recall attempts, conversational repairs, and conversational derailments. In some participants with cul de sac hyper nasal speech quality vowel ~s are not identified at all (a D3) .Ambiguities of coarticulatory nasal segment influences to conditioning of vowels for NZn reduce with decrease in degree of SNHL . Each D1 group has a different set of vowel ~ characteristics based on degree of SN hearing loss. .AhifsnhlD1 or D0 has best speech when NZn is considered due to absence of vowel~ and good projected oral speech quality. Accessibility of low frequency residual hearing and better rehabilitated hearing through modern hearing devices decline the vowel NZn occurrences, discussed in following section 11.

11. Nasalization with respect to degree of SNHL and type of hearing device use. Low frequency residual hearing in congenital Ahifsn has facilitated good oral speech quality with zero vowel ~ in analogue hearing aid users both D1 and D0 . But, with better hearing access as in severe profound (sp) and profound SNHL in D2 and D3, a definite improvement in oral vowel segment monitoring is observed with reduced incidence of vowel ~ occurrences. Initial trends in this direction can also be seen in better hearing in D1 in adult and child mssnD1 . It can be seen that even though CmssnD1 is a child with only 7 years of language exposure she is better with oralized speech quality and consistent vowel NZn performances than ApsnD1, and Aspsn no1 in D1 group with steady oral speech quality . ApsnD1 and Aspsnno1D1 have undergone more than 16 years of speech and language therapy show either fluxes to hyper nasal speech quality or hyper nasal speech quality with Cul De Sac resonances An exception is no2 AspsnD1 with hypo nasal speech quality and sporadic vowel ~ tokens discussed in the above paragraph. Both D2 and D3 groups have nasalized vowels completely in general. However, they have overcome other vowel disorders such as DZns and TZns are completely absent in these two groups (Gayathri 2019, V and VI, submission at LII) .Thus better hearing access in D2 and D3 relative to D1 in general, has helped combat some proportion of vowel nasalizations. It is emphasized that the vowel nasalizations, hyper nasal resonance and hyper nasal Cul De Sac resonance occur with different degree of persistence in D1, D2 and D3 conversations.

Figure 13. Vowel NZn is persistent AND overlapping residual vowel error in D1, D2, D3

In these last paragraphs is presented relevant artciulatory speculations for vowel NZns and nasal speech quality drawn from literature. Acoustic measures (Monsen 1979 , Subtelny, Whitehead, & Samar 1992) , accelerometer , kinematic EMG studies video naso pharyngoscopy,and nasometry (Lapine Stewart , & Tatchell 1991)are some objective measurements applied to analyze NZn in deaf . Kummer (2011) has stated that the Individuals with severe hearing loss or deafness usually demonstrate abnormal resonance due to the inability to monitor resonance. The velopharyngeal valve may close inappropriately on nasal phonemes and open on oral phonemes, causing hyper nasality, hypo nasality, or mixed resonance. In addition, cul-de-sac resonance is common in individuals who are deaf due to retraction of the tongue and deflection of the epiglottis toward the pharyngeal wall. Nasal versus oral speech is attributed to control of velopharyngeal valving. Swapna , Sreedevi, Anjali & John (2015) have inferred that the fact that increased nasality in the speech of children with congenital hearing loss is due to the inability of deaf speakers to monitor VP valving with auditory feedback. Kinematic and EMG studies from Haskins laboratories by Bell Berti (1979, 1990) identified that closure of velo -pharyngeal opening (VPO) takes an average of 250 msec. If this is a report on normal populations, in the contexts of degraded auditory access at speech production, the articulatory mechanism is put to action with varied degrees of oro sensory motor feedback involved in VPO valving. Partial velar elevations, relatively less muscular efforts at VPO, random velar closures are reported in congenital SNHL studies. . Ysunza & Vazquez (1993)'s EMG studies on deaf subjects with severe hyper nasality identified that despite normal muscle activity velopharyngeal valving activity lacked rhythm and strength during speech. It is concluded that deaf subjects may present a functional disorder of the velopharyngeal sphincter related to absence of auditory regulation during phonation. They also suggested that visual biofeedback using video naso pharyngoscopy might be useful for treating this disorder.

It is also relevant to recall expositions of A G Bell (1910) with reference to congenital SNHL showing high pitched strained voice with associated hyper nasal resonance in current study such as in ApsnD1 and an AspsnD2. His intensive experiments with vowels and vowel theories he had speculated that excessive tension in the speech mechanism was the cause of high pitched voice and this also meant excess pharyngeal constriction, such a speech mechanism according to him could cause overlaps in vowels and nullify their distinctness. He had inferred from high pitched voice of deaf to physiology of muscular constrictions including the larynx and the consequent impact of spillover to vowel distinction or indirectly to the articulatory impacts with a broader perspective of speech mechanism positionings . The diverse oscillating speech bits in the atypical D2 speaker, provides for a classic example of Bell's theory. D2 shows postural differences at his alternating speech productions. There occur dual emergences and disappearances of multiplicity of speech signs comprising of segmental and voice aspects with change in posture at speech productions in alternate speech bits of conversations. High pitch squeaky guttural voice , associated with vowel segment misarticulations comprising dissimilar substitutions ,nasalized vowels and shortened vowel duration are a cluster of signs occurring and disappearing together in this participant . Further **, most** vowel substitutions in D2 comprised the pull back ,lowered vowels at the back of oral cavity .this was termed as pocketing of vowels in the low **-**back articulatory space in previous paper (Gayathri 2016) **.** This implies a low posterior articulatory focus at speech productions and possible involvements of lingual backness towards pharynx in articulation of low back vowels not seen in

Kannada inventory. This is an extreme atypical case which however promulgates the need for further investigations in the congenital SNHL with broader perspective to unravel the unknown obscure intricacies of pharynx, larynx, lingual, velo pharyngeal involvements in future. A marked pharyngeal resonance was also reported in SNHL by Boone (1977). This study also had hypothesized that excessive pharyngeal or cul-de-sac resonance is also due to incorrect lingual retractions in the deaf. As stated earlier, there is also a possibility of a family of multi gestural speech mechanism movements reflecting on acoustic characteristics of nasalization that are not limited to, the opening of the VP port only as proposed by Carignan, Shosted, Fu, Liang & Sutton (2013). The atypicality of cluster of speech signs associated with vowel NZns and Cul De Sac speech quality in the D2speaker discussed in this paragraph opens new horizons for rethinking of nasal outcomes in voice and speech segments in the deaf. Boones hypotheses in this paragraph can be also be remotely related to other findings of restricted articulatory vowel space in the congenital SNHL (Gayathri, 2019, vowel series IV, submission at LII) . That it is possible that articulatory centralization of the vowel space an enhancement of the acoustic centralization associated with nasalization is also posited by Carignan, Shosted, Fu, Liang & Sutton (2013).

Several coarticulatory explanations also are pooled from literature to support the results in current study. Kent, Carney & Severeid (1974) identified a lower position of the velum during the production of a vowel before and after nasal consonants than for vowels near non-nasal consonants thus implying coarticulatory NZn in former contexts, which is found in stratified different degrees in SNHLD1 in current study . The same authors also found contrastive findings of velar positions between contexts of a vowel between two nasal segments and vowel between oral consonant segments. The former instances are encountered in current study. While in former contexts, velum was partially raised at vowel articulations, in latter oral contexts the velum had remained completely raised throughout the articulation. These findings possibly explain the idiosyncratic susceptibility of nasal consonant interstitial vowels to NZn in SNHL D1(11.2.3.7 and 11.2.3.3).

Some researchers have found that NZn is found in D3 speakers who were implanted at age 3-4 years , but not in those D3 speakers who were implanted at age less than 2 years Zamani, Zarandy, Borghei, Rezai & Moubedshahi (2016). Multichannel implantation in participants of current study was undertaken at age 2 year1/12 months to 3 years 5/12 months whose speech contained both presence and absence vowel NZns and hyper nasal speech quality. That , the nasalance scores of the D3 were significantly lower than those of the hearing aid users , but were higher than those of the normal control group is identified quantitatively by Swapna , Sreedevi, Anjali & John (2015).No such conclusions can be made due to relatively small sampling and qualitative approach in D1 , D2 and D3 speakers in current study .

No direct reflections on vowel nasalization occurrences with respect to speech quality at conversations can be made. Reason for this statement being several contradictory findings in these two parameters. One example which supports this proposition is that an ApsnD1 hypo nasal speech quality. Similarly, a D3 speaker with hyper nasal speech quality did not present vowel NZns in his speech corpora. Lastly, an AmssnD1 and a child mssnD1 with good oral speech quality comprise NZd vowels in their speech corpora.

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Lastly, the current study has specific implications for congenital SNHL in multilingual India. Nasalized vowels in Kannada do not affect phonemic vowel contrasts by themselves. But, in languages such as in Punjabi vowel ~ is phonemic. Then the impacts of vocalic or V ~ of congenital SNHL is even more severe than in Kannada. Therefore, acquisition of vowel inventory in Punjabi for a SNHL is even more challenging than in Kannada. Monitoring of vowel nasalization's at speech production need precisions in such languages as Punjabi for the congenital SNHL speakers.

Conclusion

Vocalic nasalization behavior in congenital SNHL after LT-CAOSLT in Kannada is a complex issue. When fundamental auditory input at vowel learning is insufficient and inefficient then the congenital SNHL may lean on alternate sensory inputs such as visual modes, particularly in D1 and D0 . But, velar movements are invisible to the SNHL speech learner. At the same time tactual feedback from velar movements are negligible. Thus there arise NZn vowel errors in their speech due to difficulty in monitoring at speech production . In addition, at the time of teaching nasal consonants in Kannada language to D1 and D0, tactual vibration from nares is model for their initial acquisitions .But this type of feedback is not fool proof to segregate nasal consonants from spread out of similar vibrations to adjacent vowels . hence there is a possibility that. adjacent vowel ~ occurs even at the time of nasal consonant learning's. The vowel NZn errors are solely termed as similar vowel substitutions in the contexts of multiple Indian languages (Gayathri 2019, vowel series II, submission LII).

Both ambiguous and consistent findings emerged with respect to residual vowel NZns and nature of speech quality. Many idiosyncratic consistencies to vocalic NZns are identified. Degree of SNHL in D1 is a contributing parameter to consistency of vowel NZns. In one of ApsnD1, participant vowel NZn and hyper nasal Cul De Sac Resonance were the only residual speech defects. Several paradoxes arise from the analyses in current study. Vowel NZn and nasal speech quality continue to persist in D2 and D3 speakers to a lesser degree. Only High frequency SNHL with accessible low frequency residual hearing with analogue hearing aids of either body level pocket type hearing aids or behind the ear level hearing aid types show good oral speech quality with zero vowel NZns. An analysis of similar participant in D2 group was not possible as this type of SNHL with D2 was not available at data sampling.

Words overlaid with stress in conversations in D1 show consistent zero vowel NZns. Some lexical contexts with NZns are perceived with greater degree of NZns than in other similar contexts. NZn in conversations is not always a steady characteristic feature. Many paradoxes which arise in results of current study are discussed. Of great interest is the dual nature of cluster of speech signs some of which are connected to speech quality and vowel NZns in an atypical D2 speaker. These lexical phonetic findings connected with vowel NZns in current study can be explored with quantitative studies in congenital SNHL in future. Unlike the other vowel errors such as the alternate vowel substitutions, DZns and TZns explored in series of vowel studies (Gayathri 2019, V, VI) which nullify to near zero occurrences in D2 and D3 compared to high occurrences in D1 speakers, the vocalic NZns are persistent in all three hearing domains D1, D2 and D3. The severity of vowel NZn range from sporadic to severe degree in this population , with an atypical occurrence . Even though the methods in current study are highly time consuming, qualitative analyses of conversational corpora brings forth many novel aspects of complex vocalic nasalization behavior in congenital SNHL speakers. Vowel nasalization in speech cannot be cannot be inferred straightaway from single speech sampling or limited speech samplings in congenital SNHL speakers. It is a complex issue dictated by phonetic, articulatory, co articulatory , lexical ,phonotactic , segmental acquisition phases ,degree and type of SNHL , variables of hearing domains D1,D2 D3 and resonance or speech quality patterns in general or even by overall speech mechanism configurations that is speculated from atypical D2 speaker . Beyond all this it is highlighted that speech quality with respect to nasalization is not a steady characteristic in conversations of at least some congenital SNHL speakers.

Limitation

Anticipatory or carry over vowel~ analyses is not done in this first phase of study on vowel ~s .

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