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Phonological Processes in Children with Hearing Impairment Using Hearing Aids and Cochlear Implant

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Abstract

The aim of the study was to assess and compare the phonological processes present in the speech of the hearing-impaired children using hearing aids and cochlear implant. A total sample of 40 children with hearing impairment divided into two groups i.e. 20 using cochlear implant with mean age of 7.71 and 20 using behind the ear hearing aids with the mean age of 7.37 participated in the study. The subjects were native Hindi speakers and attending Hindi medium special school. To assess phonological processes a test of phonology in Hindi was developed and administered. The results indicated a total of 51 processes to be occurring in speech of children with hearing aids and forty-eight in children with cochlear implants. The phonological processes consonant deletion both initial and final, palatalization, neutralization, substitution of /l/ for /r/ and lateralization were found to be statistically significantly different between both the groups. These results were partially similar to other previous studies. This study will help us in understanding and further developing better intervention techniques to improve the overall intelligibility of the speech in children with hearing impairment.

Keywords: hearing impairment, language, phonological processes, amplification devices, Hindi.

Introduction

Stampe (1973) first introduced the concept of phonological processes. A language sound system is learnt through suppression of a number of innate simplifying processes. This process of elimination or suppression of simplifying patterns in children results in acquisition of number of sound contrasts and adult like sound system.

Children with prelingual profound hearing loss usually face considerable challenges in the acquisition of verbal communication and more so with good speech intelligibility. Smith (1975) had reported numerous segmental errors which he related to poor speech intelligibility in children with hearing loss. Some of these were vowel errors, final consonant omissions of word, voiced voiceless cognates confusion and manner and place of articulation errors.

Various auditory rehabilitation devices like hearing aids or cochlear implants provide most of the hearing impaired children access to spoken language through amplification. Cochlear implantation is the current trend in the rehabilitation of the hearing impaired. This acts as a sensory aid, which converts mechanical sound energy into a coded electrical stimulus which further stimulates the auditory neural elements directly, bypassing the damaged hair cells of the cochlea. Numerous studies report increased sound repertoire and accurate articulation skills in profoundly hearing impaired children using cochlear implants compared to any other amplification device (Tobey & Hasenstab, 1991; Tobey et al, 1991).

Grogan, Barker, Dettman and Blamey (1995) examined segmental features of speech of children with hearing impairment with respect to phonetic and phonologic changes in pre and post cochlear implantation. A total of twenty subjects were divided into two groups of 10 depending on their level of intelligible speech preoperatively. The results indicated that post implant, all vowels including diphthongs, and consonants especially in the initial position of the word increased in representation. The average total percentage of correctly produced vowels, consonants, and clusters indicated a significant improvement from pre to post implantation. The most frequently occurring processes in subjects of both pre and post implant samples were in vowels prolongation, monophthongization, nasalization and in consonants voicing, stopping, deletion, and cluster reduction. Consonant deletion was the only process that was significantly reduced from pre to post implantation considerably for individual subjects. The authors concluded that the children receiving multichannel cochlear implant improve on their segmental features of speech production in everyday conversation over time. Younger children acquire more phonemes with time and use more intelligible speech. Certain vowels and consonants are more likely to be acquired, depending on the place and manner of articulation. Older children phoneme productions become more accurate with time. Gains are most likely due to a combination of maturation, habilitation, and implant experience.

A study conducted by Mines (1997) had evaluated phonological processes in 19 hearing impaired children in the age range of 5 and 12 years. The subjects were further divided into two groups depending on their hearing loss i.e. 09 with profound loss and 10 with moderate to severe hearing loss. The results indicated a significant relationship between phonological errors and degree of hearing loss. Seven phonological processes were evident in 33% of the obligatory contexts. The most commonly occurring processes were consonant deletion in final position and cluster reduction. The most common errors were with /r/ and /ʃ/ phonemes. Subjects with profound hearing loss had higher phonological errors and frequent deletion of entire clusters compared to subjects with moderate to severe hearing loss.

The advantage of using cochlear implant was also indicated by rich inventory of speech sounds in a two years post implant case study conducted by Chin & Pisoni (2000). The phonological processes reported by them in 5.8 years old were deaspiration, fronting, cluster reduction and defrication. Another study by Buhler, DeThomasis, Chute and DeCora (2007) on cochlear implant children revealed the presence of five patterns in their speech i.e. stopping, cluster reduction, final consonant deletion, velar fronting and liquid simplification.

A study was conducted by Dodd and So (1994) to identify the phonological abilities of Cantonese speaking children with hearing impairment using hearing aids. The authors concluded that the children phonological abilities were like younger speaking children and they were also using unusual phonological processes like frication, initial consonant deletion and backing.

In Indian context a study was attempted by Ramadevi (2006) on 5 to 9 years old 30 children with hearing impairment and 30 children with normal hearing. The study results indicated a significant difference between both the groups and children with hearing impairment performed poorer due to limited vocabulary and delayed language acquisition. In children with hearing impairment a total of 54 phonological processes were observed and in children with normal hearing a total of 32 phonological processes found. In hearing impaired children the phonological processes which occurred less than 20% of the subjects were epenthesis, gliding of liquids and medial vowel deletion and the frequently occurring phonological processes i.e. 20-60% were affrication, alveolar assimilation, backing, partial cluster reduction, final vowel deletion, lateralization, monophthongization, stopping of glides and liquids, voicing, vowel backing, vowel fronting, vowel lengthening, vowel raising and vowel shortening. The most commonly occurring processes i.e. >60% were cluster reduction, deaspiration, denasalization, devoicing of consonant, fronting of palatals and retroflexes, deletion, nasal deletion, stridency deletion, and vowel lowering. The author related these results to Kannada language phonetic structure and auditory perceptual problems in children with hearing impairment.

In Indian context there is a dearth in the comparative studies investigating the phonological production skills in the children with hearing impairment using cochlear implant and hearing aids. The outcomes of this study can be of great importance in indicating language specific normative of phonological processes and planning intervention in hearing impaired children. Thus, this study focuses on phonological production abilities in children with hearing impairment using cochlear implant compared to hearing aids with a similar degree of hearing loss.

Aim of the Study

To assess and compare the phonological processes present in the speech of the children with hearing impairment using behind the ear hearing aids and cochlear implant.

Methodology

Participants: A total sample of 40 children with hearing impairment (CWHI) divided into two groups equally i.e. 20 CWHI using cochlear implant (CWCI) and 20 CWHI using behind the ear hearing aids (CWHA) participated in the study. The CWHA group mean age was 7.37 and 7.71 of CWCI. All the subjects were native Hindi speakers and attending Hindi medium special school. The subjects had prelingual severe to profound sensorineural hearing loss in both the ears. The pure tone average thresholds (500, 1000 Hz & 2000 Hz) mean was 99.73 dB HL in CWHA and 108.33 dB HL in CWCI. The subjects of group I (CWCI) had a total minimum auditory experience (which includes pre implant bilateral hearing aid usage) of 57.5 months which includes a minimum of mean 37.35 months of post-implant hearing and group II (CWHA) had 45.15 months. The variables such as type of implant, speech

processor, processing strategies and no. of channels were not considered in the study. All the subjects presented normal oral peripheral mechanism both in structure and function and had no other associated problems.

Test Material: The Test for assessing phonological processes in Hindi for assessing the phonological processes was developed and used to elicit speech sample. The test tool consisted of 90 regular used Hindi words and a few English loan words (spoken in Mumbai region), which most commonly occur in the utterances of young children. All the target words were mostly bisyllabic, trisyllabic and few multisyllabic in structure. The target word list had consonants, vowels, diphthongs, & consonant clusters which were reported by Ohala (1991) (as cited in Rahul, 2006) as having higher incidence of occurrence in Hindi language. The test for assessing phonological processes in Hindi material was prepared by collecting around 216 meaningful Hindi words. This list of words was checked for familiarity by 20 parents of young Hindi speaking children and 20 parents of children with hearing impairment, and 5 Hindi medium teachers. The most familiar words which had a rating of 90% and above were selected and scrutinized for picturability, unambiguity and familiarity by presenting it to 5 normal hearing children between the age range of 3 and 5 years and 6 and 9 years in children with hearing impairment. Only the pictures correctly identified 100% of the time by subjects were accumulated. Further, these words were evaluated for content validity by two linguists and three speech language pathologists. The items analysis of all the stimuli indicated item facility to be > .7 indicating that this test is easy for the participants and in turn maximum speech samples can be elicited. This had resulted finally in the accumulation of 90 target words the pictures of which were displayed as a power point presentation (PPT). In addition, two story charts were also used to assess phonological processes in spontaneous speech i.e. story of a "rat and loin" and "thirsty crow".

Procedure

After seeking the consent from the parents of the participants, the participants were made to sit comfortably in front of the laptop in a quiet, well lit room. Task I involved picture naming task using Test for assessing phonological processes in Hindi and Task II involved eliciting spontaneous speech using story charts. In Task I the pictures were presented one by one using a PPT presentation on laptop with an LCD screen of 15.5 inches. The researcher instructed in Hindi to the child that "you will see a picture one after another in the laptop. Look at them carefully and name the picture". Initially the researcher presented three practice pictures in order to familiarize the children with test procedure. Each stimulus was presented at a duration of 1 minute and short breaks were given in between whenever children felt tired. The story narration task involved subject to look at the story chart and narrate. Whenever the subjects would fail to narrate, they were involved in a conversation to elicit a continuous speech sample. The participant's responses obtained in both the tasks were recorded using Sony digital recorder, if the responses obtained were correct a tick was put beside the target word and if incorrect it was simultaneously transcribed in broad IPA beside the target word in the assessment sheet. The duration of the testing ranged from 30 to 40 minutes for each child.

The recorded responses of each child were fed into media player which was routed through laptop. These responses were played back through earphones. The researcher listened them carefully

and transcribed them in broad IPA. Each word as a whole was analysed for the phonological processes. This whole word method has more advantages, since some children may say the target sound correctly but may misarticulate another sound in the word (Ramadevi, 2006). The obtained data was further analysed for mean percentage of occurrence of phonological processes and whether they are developmental or atypical.

Reliability Measures: In order to establish inter judge reliability, 10% of the speech samples were randomly transcribed by an experienced speech language pathologist. The inter judge agreement was found to be 91.76% for the selected samples.

Data Analysis: Each word in the sample obtained was analysed as a whole for all the participants and the percentage of occurrence of each phonological process calculated. The percentage of subjects exhibiting the phonological process were further classified into three categories as described by Ramadevi (2006) i.e. occasionally occurring (less than 20%), frequently occurring (20 to 60%) and most commonly occurring (more than 60%).

Statistical Analysis: The mean and standard deviation was calculated for all the subjects i.e. CWCI and CWHA. The data were further subjected to Independent t test to find out significant differences in the mean percentage of occurrence of phonological processes in both the groups.

Results and Discussion

On overall observation of the results a total of fifty one phonological processes were found to be occurring in the speech of CWHA and forty eight in CWCI. The groups differed in the mean percentage of occurrence of phonological processes; however, it was not statistically significant. These findings are almost similar to the findings of Ramadevi (2006) study on CWHI in Kannada where in a total of 54 processes been identified in the speech of children with hearing impairment. The total percentage of phonological processes used in CWHA was 47 and 42 in CWCI. These findings are displayed in Table 1.

Table 1. The mean and SD values of phonological processes in both CWHA and CWCI.

Groups	Mean	SD	P value
CWHA	0.483	0.22	>0.05
CWCI	0.432	0.23	

Further, on applying independent t test on each phonological process to evaluate significant difference between both the groups, the phonological processes consonant deletion both in initial and final position of a word, palatalization, neutralization, substitution of /l/ for /r/ and lateralization were found to be statistically significantly different ($p<0.05$). Among these processes except for neutralization all were highly occurring in the speech of CWHA. The findings of substitution of /l/ for /r/ and cluster reduction are similar to findings of Mines (1997) study who evaluated phonological processes in 19 hearing impaired children between the age range of 5 and 12 years. These findings are displayed in Table 2.

Table 2. The mean percentage of occurrence of phonological processes in CWHA and CWCI.

S.no	Phonological processes	CWHA		CWCI		T-value	St. dev	P-value
		Mean	SD	Mean	SD			
1.	Weak Syllable deletion	20	0.41	30	0.47	-0.717	0.441	0.48
2.	ICD	65	0.49	30	0.47	2.31	0.480	0.027*
3.	FCD	95	0.22	20	0.41	7.18	0.330	.0001*
4.	Total CR	50	0.51	50	0.51	0.309	0.512	0.76
5.	Partial CR	85	0.37	100	0.00	-1.83	0.259	0.075
6.	Cluster Substitution	70	0.47	50	0.51	1.29	0.492	0.21
7.	Dimunitization	65	0.49	50	0.51	0.946	0.501	0.35
8.	Epenthesis	65	0.49	70	0.47	-0.330	0.480	0.74
9.	Reduplication	50	0.51	50	0.51	0.00	0.513	1.00
10.	Coalescence	65	0.49	40	0.50	1.59	0.496	0.12
11.	Glottal replacement	10	0.31	0	0.00	1.45	0.218	0.15
12.	Stopping	90	0.31	70	0.47	1.59	0.397	0.12
13.	Fronting	50	0.51	70	0.47	-1.29	0.492	0.21
14.	Backing	50	0.51	50	0.51	0.00	0.513	1.00
15.	Affrication	70	0.47	80	0.41	-0.71	0.441	0.48
16.	Palatalization	35	0.49	70	0.47	-2.31	0.480	0.02*
17.	Depalatalization	75	0.44	80	0.41	-0.37	0.428	0.71
18.	Gliding	65	0.49	50	0.51	0.946	0.501	0.35

19.	Vocalization	65	0.49	40	0.50	1.59	0.496	0.12
20.	Denasalization	45	0.51	40	0.50	0.312	0.507	0.76
21.	Neutralization	75	0.44	30	0.47	3.11	0.457	0.00*
22.	Labial assimilation	5	0.22	10	0.30	-0.58	0.269	0.56
23.	Velar assimilation	35	0.49	20	0.41	1.05	0.452	0.30
24.	Alveolar assimilation	40	0.50	60	0.50	-1.26	0.503	0.22
25.	Nasal assimilation	30	0.47	50	0.51	-1.29	0.492	0.21
26.	Syllable deletion	15	0.37	20	0.41	-0.40	0.389	0.69
27.	Metathesis	20	0.41	40	0.50	-1.38	0.459	0.18
28.	Substitution of /r/ to /l/	85	0.37	40	0.50	3.24	0.440	0.00*
29.	Migration	35	0.49	30	0.47	0.330	0.480	0.74
30.	Prevocalic voicing	25	0.44	40	0.50	-1.00	0.474	0.32
31.	Postvocalic voicing	10	0.31	10	0.30	0.00	0.308	1.00
32.	Prevocalic devoicing	65	0.49	50	0.51	0.946	0.501	0.35
33.	Postvocalic devoicing	50	0.51	60	0.50	-0.62	0.508	0.54
34.	MCD	70	0.47	90	0.31	-1.59	0.397	0.12
35.	Bilabialization	20	0.41	10	0.31	0.872	0.363	0.39
36.	Vowel backing	60	0.50	70	0.47	-0.65	0.487	0.52
37.	Vowel lowering	40	0.50	60	0.50	-1.26	0.503	0.22
38.	Vowel unrounding	35	0.49	20	0.41	1.05	0.452	0.30

39.	Diphthongization	35	0.49	40	0.50	-0.319	0.496	0.75
40.	Monophthongization	70	0.47	50	0.51	1.29	0.492	0.21
41.	Vowel lengthening	70	0.47	60	0.50	0.650	0.487	0.52
42.	Deaspiration	65	0.49	80	0.41	-1.05	0.452	0.30
43.	Frication	50	0.51	40	0.50	0.623	0.508	0.54
44.	Vowel shortening	55	0.51	45	0.51	0.620	0.510	0.54
45.	Nasalization	55	0.51	30	0.47	1.61	0.491	0.12
46.	Lateralization	25	0.44	0	0.00	2.52	0.314	0.01*
47.	Vowel deletion	15	0.37	0	0.00	1.83	0.259	0.07
48.	Vowel fronting	30	0.47	40	0.50	-0.65	0.487	0.52
49.	Sound intrusion	35	0.49	40	0.50	-0.319	0.496	0.75
50.	Palatal assimilation	40	0.50	20	0.41	1.38	0.459	0.18
51.	Aspiration	20	0.41	10	0.31	0.872	0.363	0.39
	Total % of occurrence	0.483	0.22	0.432	0.23	17	1.10	0.27

*Statistically significant

The subjects of both the groups i.e. CWHA and CWCI were found to be exhibiting typical and atypical phonological processes. The atypical processes exhibited by subjects of both the groups were initial consonant deletion, glottal replacement, backing, denasalization, medial consonant deletion, metathesis, migration and bilabialization. These findings are similar to findings reported by Lee (2010) and Day et al. (2010). However, a study conducted by Eriks-Brophy, Gibson & Tucker (2013) on 25 children with hearing loss attending auditory-verbal intervention at the ages of 36, 48, and 60 months reported suppression of atypical processes by the age of five years which is contradictory in the present study. The persistence of processes above the age of suppression in the present study could be related to perceptual feedback issues, neuromotor control of articulation, habituation of error patterns and linguistic and phonological rules knowledge as stated by Smith (1975).

The findings of qualitative analysis of data are as following:

The first important finding from the results was the most commonly occurring phonological processes (60% and above) to be more in Group I CWHA i.e. 20 compared to Group II CWCI i.e. 14. Among these the phonological processes, initial consonant deletion, final consonant deletion, stopping, gliding, vocalization, neutralization, substitution of /l/ for /r/, prevocalic devoicing, monophthongization and vowel lengthening were found to be higher in percentage of occurrence of speech of CWHA compared to CWCI. Whereas, the phonological processes, partial cluster reduction, epenthesis, fronting, affrication, palatalization, depalatalization, alveolar assimilation, postvocalic devoicing, medial consonant deletion, vowel backing, vowel lowering and deaspiration were higher in occurrence of speech of CWCI compared to CWHA. These findings indicate that both the groups of subjects differed in the type of phonological processes most commonly used. The findings are displayed in Table 3.

Table 3. Classification of phonological processes according to their frequency of occurrence across both the groups.

20% or less - occasionally occurring		**20-60% frequently occurring**		**60% and above as most commonly occuring**	
CWHA	**CWCI**	**CWHA**	**CWCI**	**CWHA**	**CWCI**
Weak syllable deletion (20)	Final consonant deletion (20)	Total cluster reduction (50)	Weak syllable deletion (30)	ICD (65)	Partial cluster reduction (100)
Glottal replacement (10)	Labial assimilation (10)	Reduplication (50)	ICD (30)	FCD (95)	Epenthesis (70)
Labial assimilation (5)	Velar assimilation (20)	Fronting (50)	Total cluster reduction (50)	Partial CR (85)	Stopping (70)
Syllable deletion (15)	Syllable deletion (20)	Backing (50)	Cluster substitution (50)	Cluster Substitution (70)	Fronting (70)
Metathesis (20)	Postvocalic voicing (10)	Palatalization (35)	Dimunitization (50)	Dimunitization (65)	Affrication (80)
Postvocalic voicing (10)	Bilabialization (10)	Denasalization (45)	Reduplication (50)	Epenthesis (65)	Palatalization (70)
Bilabialization (20)	Vowel unrounding (20)	Velar assimilation (35)	Coalescence (40)	Coalescence (65)	Depalatalization (80)
Lateralization (25)	Palatal assimilation (20)	Alveolar assimilation (40)	Backing (50)	Stopping (90)	Alveolar assimilation (60)

Vowel deletion (15)	Aspiration (10)	Nasal assimilation (30)	Gliding (50)	Affrication (70)	Postvocalic devoicing (60)
Aspiration (20)		Migration (35)	Vocalization (40)	Depalatalization (75)	MCD (90)
		Prevocalic voicing (25)	Denasalization (40)	Gliding (65)	Vowel backing (70)
		Post vocalic devoicing (50)	Neutralization (30)	Vocalization (65)	Vowel lowering (60)
		Vowel lowering (40)	Nasal assimilation (50)	Neutralization (75)	Vowel lengthening (60)
		Vowel unrounding (35)	Metathesis (40)	Substitution of /r/ to /l/ (85)	Deaspiration (80)
		Diphthongization (35)	Substitution of /r/ to /l/ (40)	Prevocalic voicing (65)	
		Frication (50)	Migration (30)	MCD (70)	
		Vowel shortening (55)	Prevocalic voicing (40)	Vowel backing (60)	
		Nasalization (55)	Prevocalic devoicing (50)	Monophthongization (70)	
		Vowel fronting (30)	Diphthongization (40)	Vowel lengthening (70)	
		Sound intrusion (35)	Monophthongization (50)	Deaspiration (65)	
		Palatal assimilation (40)	Frication (40)		
			Vowel shortening (45)		
			Nasalization (30)		

			Vowel fronting (40)		
			Sound intrusion (40)		

The second finding was frequently occurring (20-60%) phonological processes to be higher in CWCI i.e. 25 compared to CWHA i.e. 21. Among these the processes which were more frequent in CWHA group were denasalization, velar assimilation, migration, vowel unrounding, frication, vowel shortening, nasalization and palatal assimilation. The processes which were higher in frequency in CWCI group were weak syllable deletion, nasal assimilation, metathesis, prevocalic voicing, diphthongization, vowel fronting and sound intrusion. The processes total cluster reduction, reduplication, and backing were found to occurring with similar frequency (50%) in both the groups of subjects.

The third finding of less frequently occurring (less than 20 %) phonological processes was found to be almost similar in both the groups of CWHI i.e. 10 in CWHA and 9 in CWCI. The processes were different in both the groups of subjects except for labial assimilation, syllable deletion, postvocalic voicing, bilabialization, and aspiration. These findings were partially similar to the findings of Ramadevi (2006) study in hearing impaired children.

Summary and Conclusion

The overall results of the study reflected a delayed phonological development in CWHI using both hearing aids and cochlear implant. On qualitative evaluation some of the processes were found to be occurring more in children using hearing aids and some in children using cochlear implant. The understanding of the pattern of processes (typical or atypical) in hearing impaired children will help speech language pathologists in utilizing or developing better intervention techniques to improve the overall intelligibility of their speech.

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