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Perception of Marathi consonant manner contrasts in children with and without hearing impairment

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ABSTRACT

Background: Very few published studies have reported phoneme contrasts in children with and without hearing impairment in Indian languages. The present study is aimed at comparing perception of manner contrasts in 6 to 8 year old Marathi children with normal hearing and those with hearing impairment using hearing aids and cochlear implants.
Methods: Two hundred 6 to 8 year olds participated across three groups: 106 with normal hearing (NH), 47 with hearing aids (HA) and 47 with cochlear implants (CI). Perception of four consonant manner contrasts was assessed using a four-alternative, forced choice picture-pointing task using recorded minimal pairs with CVC or CVCV words: a) Stop vs. Fricative; b) Stop vs. Nasal; c) Stop vs. Affricate and d) Aspiration.
Results: All NH participants obtained ceiling scores for stop vs. fricative and stop vs. nasal contrasts. NH participants performed significantly better than participants with CI on all contrasts. Performance of HA participants was more variable and significantly poorer than the CI participants. Children implanted at or before 4 years of age and those using CI for more than 2.5 years performed consistently better on all contrasts as compared to those implanted after 4 years of age and using it for less than 2.5 years. Children fitted with HA at or after 2.5 years of age performed consistently better than those fitted before 2.5 years of age. Participants with average hearing aided thresholds 45 dB HL or lower (better) performed better than those with average aided thresholds above 45 dB HL.
Conclusions: Normative data on perception of various manner contrasts in Marathi is generated. Phoneme perception skills of children with NH are significantly better than those of children with CI and HA.

Keywords: Manner contrast, Cochlear implants, Hearing aids, Normal hearing, Stops, Fricatives, Nasals, Affricates, Aspiration

INTRODUCTION

The term "Speech Perception" implies the entire process involved in the receptive component of verbal communication. However, in practice, it is mostly used to refer to the process by which the motor/acoustic patterns of speech become linguistic structures in the listener's mind.[1] According to Rvachew and Grawburg, speech perception is the process of transforming a continuously changing acoustic signal into discrete linguistic units.[2] The smallest linguistic unit of a language is the phoneme, which when combined with other phonemes forms meaningful units such as words. It is the smallest contrastive linguistic unit as it can bring about a change in the meaning. Auditory discrimination and identification of these contrasting phonemes is an important ability for auditory perception of speech.

Human infants are born with pre-adaptive processes that enable them to respond to speech stimuli in a favourable manner, even as early as day one after birth. The infant demonstrates amazing perceptual capabilities within few weeks after birth, which lead us to believe that in addition to the native endowment that the infant is bestowed with; there has been sufficient auditory exposure and experience before birth. The ability to perceive speech improves as the child matures and this development is a complex interaction between the genetically available pre-adaptive processes and the exposure and experience obtained from the language spoken in the environment.

Evidences from infant speech perception studies demonstrate that phonetic discrimination abilities are very sophisticated even at a very early age and these abilities appear to be independent of the native language of the infant.[3-9] Infants can discriminate minimally different phonemes – even those not in their language; however, as they grow up – somewhere between 9 and 12 months only phonemic contrasts present in the native language are maintained while others are lost permanently.

Several studies have reported on phoneme perception skills and the link between perception and production in infants and children with normal hearing.[3-18] Some of these studies suggest that development of vowel and consonant perception is largely complete in the first few years of childhood – around 5 to 6 years of age, with some aspects refining till the adolescent years; while some studies have reported less than ceiling scores even for children as old as 10 to 12 years.[14,17,19]

For normal development of speech perception and production in the early years and for appropriate and typical use of verbal communication through life, the hearing sense needs to be intact. It is the auditory system that constrains speech perception. The auditory information received by a child with hearing impairment is inadequate and hence does not permit accurate prediction of the idea that the speaker wishes to convey. The primary effect of the hearing impairment is to reduce the amount of auditory information available to the individual, resulting in a restricted awareness of the world around him or her. Speech stimuli in the environment are inaccessible, too. As the perceptual system of a child with hearing impairment matures, it gets organized without incorporating auditory information and the longer the child stays without access to auditory information, the more stabilized this non-auditory perceptual organization becomes.[20]

The effect of hearing impairment on auditory perception is determined by several factors. Variables pertaining to the hearing impairment itself are of primary importance. The degree of impairment, its configuration, its onset and nature, all determine the amount of auditory information available to the individual. In children born with a hearing impairment, these variables will determine how much of auditory perceptual development will occur in the child. Further, the type of hearing device the child is fitted with, the age at fitting of the hearing device, benefit from the device, and quality of training the child receives are all important factors determining speech perception outcomes. Children having associated problems generally have poorer outcomes as compared to those who do not. Several studies have compared speech perception abilities in children with cochlear implants with those using hearing aids as well as those with normal hearing.[17,21-28]

India is a diverse country with a number of languages spoken across its length and breadth. The 2001 Census of India recorded 29 individual languages as having more than 1 million native speakers. According to Ethnologue, the number of individual languages listed for India is 461 of which 447 are living. Marathi, the language of Maharashtra state, is one of the major Indo-Aryan languages of India. It is one of the eighteen official languages in the country. There are approximately sixty-two million speakers of Marathi, including speakers outside the native state of Maharashtra.[29] According to Thirumalai and Gayathri, in Indian languages, the following acoustic values have to be identified: vowels as opposed to consonants, opposition between long and short vowels, rounded and un-rounded vowels, high, mid and low vowels, voiced-voiceless contrast, aspirated as opposed to un-aspirated consonants, manner of articulation, place of articulation and tone, in languages that are tonal in nature.[30]

Very few published studies have reported phoneme contrasts in children with and without hearing impairment in Indian languages. Raja et al investigated perception of phoneme contrasts in children with and without hearing impairment in the age range of 8 to 12 years.[17] They compared perception of vowel and consonant contrasts in children with hearing impairment using cochlear implants and hearing aids with that in children with normal hearing in Telugu language using the auditory-only and auditory-visual modality. 15 participants were included in each subject group and minimal pairs of Telugu words were used as stimuli. They found that children with normal hearing performed better than children with hearing impairment and all subject groups performed better for vowel contrasts than for consonant contrasts. Among the children with hearing impairment, children with cochlear implants performed better than those using hearing aids. Children with no hearing loss performed almost similar in auditory-only and auditory-visual conditions, while those with hearing impairment performed better in the auditory-visual condition. They reported mean percentage scores on 85% and 86% for children with normal hearing for the vowel and consonant contrasts respectively for the auditory-only condition.

The present study is aimed at studying and comparing perception of manner contrasts in 6 to 8 year old Marathi children with normal hearing and those with hearing impairment using hearing aids and cochlear implants. The age range of 6 to 8 years was included as children in this age group are likely to be still undergoing development in some aspects of speech perception, while other aspects are likely to be developed and well established. Of the phoneme contrasts that are important for auditory perception of speech, perception of manner of articulation contrasts is reported in this paper. The contrasts were examined through a closed-set word recognition task using minimal pairs as stimuli.

METHODS

Clearance for the study was obtained from the Ethics Committee of AYJNISHD(D) and the study was conducted between 2013 and 2015 at the institute.

Participants

A total of 200 children in the age range of 6 to 8 years participated in the study. These children were enrolled using purposive sampling and were divided into three groups:

Group 1: Children with normal hearing (NH)

This group consisted of 106 children. Children were included in this group if they were between 6 to 8 years of age, had Marathi home backgrounds, attended Marathi medium schools, and passed pure tone screening at 20 dBHL for both ears for frequencies 250 through 4000 Hz. They were recruited across three Marathi medium schools in the western suburbs of Mumbai. A letter detailing the inclusion criteria for the participants and the test procedure to be administered on them was sent to the principals of these schools. A list of all children in the age range of 6 to 8 years was prepared by the school authorities for the researcher. The consent of the parents was sought through the school authorities. Only children whose parents gave consent were considered for inclusion as participants. Additionally, for children who were above 7 years of age, assent was obtained after explaining the test procedure to the child. All children were given a questionnaire to be taken home and filled by the parents. The questionnaire had questions about the child's speech and language development milestones and about symptoms of hearing loss. Only children whose parents reported no history or complaint of any language, speech, learning problems and symptoms related to ear disease or hearing loss were included.

Group 2: Children with pre-lingual severe to profound hearing impairment using unilateral cochlear implants (CI)

This group consisted of 47 children. Inclusion criteria for this group consisted of the following: chronological age between 6 and 8 years, Marathi as the language spoken at home and medium of instruction at school, unaided air conduction pure tone average at the frequencies 500, 1000 and 2000 Hz >70 dB HL in the better ear, multichannel CI used in one ear "all day every day" with or without a HA in the other ear, three-frequency average CI assisted warble tone thresholds between 30 and 45 dB HL, use of CI for at least six months, a minimum of 1 year of intervention in a predominantly aural-oral program, average to above average performance in a special or regular school, no cochlear deformity or auditory nerve anomaly, no serious associated impairments such as mental retardation, cerebral palsy, autism, as ascertained by a checklist incorporating DSM IV criteria. Only children whose parents gave consent were included as participants.

Group 3: Children with pre-lingual severe to profound hearing impairment using binaural behind-the- ear hearing aids (HA)

This group consisted of 47 participants. The inclusion criteria for this group were similar to those for group 2, except children in this group used binaural behind-the-ear hearing aids for a minimum of 2 years and attended intervention in a predominantly aural-oral program for more than 2 years. Only children whose parents gave consent were included.

Stimulus material

The perception of consonant manner contrasts was assessed using a four-alternative, forced choice task with a picture-pointing response mode. Picture plates were constructed with four pictures on each plate, of which two were target items and two were foils. Four manner contrasts were assessed: a) Stop vs. Fricative; b) Stop vs. Nasal; c) Stop vs. Affricate and d) Aspiration. Stimuli consisted of minimal pairs with CVC or CVCV words. To begin with, for each of the four manner contrasts, prospective stimulus words (rhyming words) were chosen from the vocabulary appropriate for children in the age range of 6 to 8 years. These were obtained from the first author's own experience of working with children in this age group and by consulting school books used with children of this age. Out of this large pool of items, words that could not be depicted using pictures were omitted. The words that could be suitably depicted using pictures were then given to ten parents of ten normal hearing children and ten parents of ten children with bilateral severe to profound hearing impairment for familiarity rating. Words rated as very familiar by at least eight out of ten parents were used as stimulus items, while others were either rejected or used as foil items. The stimulus words that were thus selected mainly consisted of nouns and few verbs that could be depicted using appropriate pictures. All the pictures were coloured photographs of objects photographed by the author or used from Internet sources without any copyright issue. Each word-picture pair was then subjected to ratings by three speech-language pathologists who were native speakers of Marathi language in order to establish that the picture unambiguously depicted the target word. This was done in verbal discussion with each SLP separately and wherever required, pictures were changed to choose more appropriate and unambiguous ones.

Table 1: shows the number of stimulus items included and the position in the word where the target phoneme was placed for each of the manner contrasts targeted.

	No. of test plates	No. of stimulus words/ maximum score obtained	Contrasts assessed
Stop v/s Fricative	10	20	/k-ʃ/, /d̲-̲h/, /t̲-s/, /p-s/*, /ʈ-s/(final), /b-s/, /d̲-h/, /ɖ-s/, /k-s/
Stop v/s Nasal	8	16	/p-n/, /k-m/, /b-m/, /p-m/*, /p-n/ (final), / ʈ-ɳ/, /g-n/
Stop v/s Affricate	8	16	/d̲-ʧ/, /p-ʦ/, /d̲-ʦ/, /b- ʦ/*, /t̲-̲ ʦ/, /p-ʦ/ (final), /ʈ-ʦ/ (final),
Aspiration	4	8	/t̲-̲tʰ/, /ʤ-ʤʰ/, /g-gʰ/, /p-pʰ/

*denotes that the pair of phonemes was assessed in two different pairs of stimuli. All pairs other than those denoted as final were assessed in word initial position.

Selected stimulus words spoken by an adult female speaker were recorded in a professional studio by a sound engineer using Nuendo version 4.0. The recording was saved as a single wav file. An interval of six seconds was given between two stimulus items to leave enough time for the child to point to the appropriate picture and for the examiner to turn over the test plate. A calibration tone of 1000Hz was created, with root-mean-square levels equal to that of the words so that the gain of the audiometer could be adjusted prior to testing. Stimuli were presented in the auditory-only condition via GSI 61 Diagnostic Audiometer. From the headphone output of a Dell laptop computer a connection was made to the external input of the audiometer, using a stereo cable with 3.5 mm RC pins.

Test administration

Normal hearing children

Normal hearing participants were tested in their school environment in a small quiet room relatively free of reverberant surfaces during a quiet time of the day. The test was administered directly through laptop connected to speakers. To calibrate the test setup, the recorded stimuli were played via a Dell laptop connected to Mosto 2.0 loudspeakers placed at 45° azimuth. The microphone of a Bruel & Kjaer-Type-2250 sound level meter (SLM) was held at a distance of 1 m from the speakers and measurements were made as the stimuli were played from the laptop. The SLM was set on "fast" mode. The volume of the speaker was manipulated till readings between 55-60 dB SPL were consistently obtained on the SLM. The volume setting on the speaker which resulted in this intensity was marked to enable consistent setting during test presentation. Also, an application on the iPad called "Sound Meter" was used during this measurement session and before seating each participant, to ensure that the correct distance from the speaker was maintained. During testing, the speakers were placed exactly at the same distance and azimuth as during this calibration procedure. The laptop was placed in front of the tester who sat beside the child. A folder consisting of printed test plates with pictures was placed right in front of the child and the tester flipped the page when it was time for the test plate to be changed. Participants were instructed that "You will hear words from the loudspeaker and will be shown pictures in front of you, listen carefully which word is said and point to the respective picture." Two practice plates were administered first in similar testing condition. These were not scored. It only formed a basis to judge whether the participant had understood the task and to give a sample of what could be expected. A score of one point was given for each correct response and an incorrect response was scored as zero. Total score for each of the four contrasts was then calculated.

Subjects with hearing impairment

Participants from the cochlear implant group and hearing aid group were tested in a two-room sound field setup. They were comfortably seated on a chair, with two loudspeakers placed at the left and right of the midline, at 1-meter distance and 45-degree azimuth. For subjects using hearing aids, the speaker on the side of the ear with better aided PTA thresholds was used to present the stimuli, while for children with cochlear implants the speaker on the side of the implanted ear was used to present the stimuli. The presentation level was 60 dB HL with the child's hearing device placed on. Instructions and scoring was the same as for normal hearing participants.

Statistical analysis

Mean scores and standard deviations were computed for the four manner contrasts for each of the three groups. Repeated measures Analysis of Variance was performed to compare the performance between the three groups and within each group for the four contrasts. Post-hoc analysis was done using Bonferroni corrections for pairwise comparisons.

RESULTS

Table 2 shows the details of the participants included in the three groups. Children with mild attention deficits were not excluded from the sample; 11 out of the 47 participants in CI group had history of mild attention deficits or had it at the time of the study. Forty-four of the participants were using an implant device from Cochlear Ltd, while one and two participants each had a device from Neurelec and Advanced Bionics, respectively. Out of the 47 participants, 18 used a hearing aid in the contralateral ear, with mean aided three frequency average of 54.99 dB HL. However, they were tested in the CI-only condition for the purpose of this study. Three of the participants in the HA group had been diagnosed and treated for ADHD in the past. However, with treatment the attention had improved considerably and for all the three participants the complete test could be administered in a single session without any problems.

Table 2: Details of the participants included in the study.

Group	Sex	N	Age		Duration of device use (years)		Better ear aided/ CI assisted thresholds (dBHL)		Age at fitting of device (years)	
			Mean	SD	Mean	SD	Mean	SD	Mean	SD
NH	Male	46	6.76	0.510						
	Female	60	6.94	0.498						
	Total	**106**	**6.87**	**0.508**						
CI	Male	22	7.04	0.739	2.84	1.521	32.87	7.869	4.25	1.632
	Female	25	6.81	0.645	2.85	1.007	33.72	4.674	4.01	1.059
	Total	**47**	**6.92**	**0.694**	**2.85**	**1.259**	**33.32**	**6.313**	**4.12**	**1.348**
HA	Male	24	7.04	0.690	4.53	1.219	47.62	8.129	2.53	0.926
	Female	23	6.92	0.535	4.28	1.010	43.24	8.306	2.64	1.727
	Total	**47**	**6.98**	**0.615**	**4.41**	**1.117**	**45.47**	**8.423**	**2.59**	**1.044**

Table 3: Mean scores, SD and range of scores obtained by the three groups.

Contrast	Group	Mean	Standard deviation	Standard error	Minimum	Maximum
Stop/Fricative	NH	20	0	0	20	20
	CI	17.38	2.419	0.353	9	20
	HA	13.19	4.292	0.626	6	20
Stop/Nasal	NH	16	0	0	16	16
	CI	13.17	2.150	0.314	9	16
	HA	10.55	2.329	0.340	6	15
Stop/ Affricate	NH	15.97	0.216	0.021	14	16
	CI	12.85	1.706	0.249	10	16
	HA	10.21	2.726	0.398	4	16
Aspiration	NH	7.51	0.771	0.75	5	8
	CI	5.19	1.541	0.225	3	8
	HA	4.26	2.201	0.321	0	8

Table 4: ANOVA and Bonferroni results for the four manner contrasts.

	Stop/Fricative	Stop/Nasal	Stop/Affricate	Aspiration
ANOVA				
F-Value	134.056	216.099	234.724	101.643
Significance	0.000*	0.000*	0.000*	0.000*
Bonferroni				
NH-CI				
Mean difference	2.617	2.830	3.121	2.318
Significance	0.000*	0.000*	0.000*	0.000*
NH-HA				
Mean difference	6.809	5.447	5.759	3.254
Significance	0.000*	0.000*	0.000*	0.000*
CI-HA				
Mean difference	4.191	2.617	2.638	0.936
Significance	0.000*	0.000*	0.000*	0.005*

The mean scores, SD, minimum and maximum scores obtained for the four manner contrasts for the three participant groups are shown in Table 3. The scores from Table 3 indicate that the identification of stop vs. fricative and stop vs. nasal contrasts is acquired by all normal hearing participants by this age, while the identification of stop vs. affricate and aspiration contrasts is not fully acquired by the age of 8 years. Children with CI and HA are still in the process of acquiring these contrasts. The mean scores of the CI group are higher than that of the HA group for all four manner contrasts and SD for HA group is higher, indicating greater variability in scores in the HA group for all four contrasts. Also, the scores for the CI and HA group are spread over a greater range as compared to that of the NH group. Very few participants from the CI and HA groups obtained the maximum possible score for all the four contrasts.

The results of the ANOVA and the post-hoc analysis are shown in Table 4. The ANOVA results indicate a significant difference (p=0.000) between the average scores of the three participant groups for all the four manner contrasts. Results of the Bonferroni group-wise comparisons indicate a significant difference for the three group comparisons for all the four manner contrasts.

Age at implantation

CI group comprised children implanted between 1.58 to 7.5 years, with mean age at implantation being 4.12 years. The group was further divided into two: age at implantation </= 4 years (26 participants), and age at implantation > 4 years (21 participants). Scores of these two groups of participants were compared using t-tests for each of the contrasts. Mean scores and SDs for each of the four contrasts along with the results of the t tests computed to compare the performance of participants implanted at or before 4 years of age and those implanted after the age of 4 years are shown in Table 5. As seen in Table 5, the mean scores of participants with CI implanted at or before 4 years of age are greater than those for participants implanted after 4 years of age for all contrasts. The SD values do not show a consistent pattern across the contrasts: they are greater for participants implanted after 4 years of age for aspiration contrast; while for the other three contrasts the SD values are greater for the participants implanted at or before 4 years of age. Independent Samples t-tests indicate a significant difference between the mean scores of participants implanted at or before 4 years of age and those implanted after 4 years of age for the stop vs. nasal contrast.

Table 5: Mean, SD and t-test results according to age at implantation.

Contrast	Age at CI	N	Mean	SD	t-value	df	Sig (2-tailed)
Stop/fricative	</= 4 years	26	17.92	2.432	1.741	45	0.089
	> 4 years	21	16.71	2.283			
Stop/nasal	</= 4 years	26	13.73	2.201	2.058	45	0.045*
	> 4 years	21	12.48	1.914			
Stop/affricate	</= 4 years	26	13.12	1.505	1.187	45	0.242
	> 4 year	21	12.52	1.914			
Aspiration	</= 4 years	26	5.42	1.419	1.150	45	0.256
	> 4 years	21	4.90	1.670			

Table 6: Mean, SD and t-test results according to duration of use of CI.

Contrast	Duration of CI use	N	Mean	SD	t-value	df	Sig (2-tailed)
Stop/fricative	</=2.5 years	19	16.95	2.147	-1.017	45	0.314
	> 2.5 years	28	17.68	2.583			
Stop/nasal	</=2.5 years	19	12.53	1.926	-1.727	45	0.091
	> 2.5 years	28	13.61	2.217			
Stop/affricate	</=2.5 years	19	12.47	1.775	-1.257	45	0.215
	> 2.5 years	28	13.11	1.641			
Aspiration	</=2.5 years	19	5.05	1.649	-.505	45	0.616
	> 2.5 years	28	5.29	1.487			

Duration of CI use

T-tests were also computed to compare the performance per the duration of implant use, wherein participants were divided into two groups: duration of implant use </= 2.5 years (19 participants) and duration of implant use > 2.5 years (28 participants). Mean scores and SDs for each of the contrasts along with the results of the t tests computed to compare the performance of participants using the implant for 2.5 years or less and those using the implant for more than 2.5 years are shown in Table 6.

As can be seen from Table 6, the mean scores of participants using CI for more than 2.5 years are higher than those for participants using the CI for 2.5 years or less for all contrasts. The SD values do not show a consistent pattern across the contrasts; they are greater for participants using CI for 2.5 years or less for contrasts stop/affricate and aspiration; while for the other contrasts the SD values are greater for the participants using CI for 2.5 years or more. Independent Samples t-tests indicate no significant difference between the mean scores of participants using the CI for 2.5 years or less and those using it for more than 2.5 years for the four contrasts. The performance of HA group was further analysed with reference to two variables

Age at first hearing aid fitting

HA group had children who were fitted with hearing aids between 0.75 to 5.08 years, with mean age at fitting being 2.59 years. This group was further divided into two: age at fitting < 2.5 years (21 participants), and age at fitting >/= 2.5 years (26 participants).

Scores of these two groups were compared using t-tests for each of the contrasts. Mean scores and SDs for each of the contrasts along with the results of the t tests computed to compare the performance of participants first fitted with HA before 2.5 years of age and those fitted at or after the age of 2.5 years are shown in Table 7.

As can be seen from Table 7, the mean scores of participants first fitted with hearing aids at or after 2.5 years of age are higher than those for participants fitted with hearing aids before 2.5 years of age for all contrasts. The SD values are greater for participants fitted before 2.5 years of age for all contrasts except stop/fricative, where the SD values are greater for the participants fitted at or after 2.5 years of age. Independent Samples t-tests indicate that the difference between the mean scores of participants fitted before 2.5 years of age and those fitted at or after 2.5 years of age is not significant for any of the contrasts.

Table 7: Mean, SD and t-test results according to age at HA fitting.

Contrast	Age at HA fitting	N	Mean	SD	t-value	df	Sig (2-tailed)
Stop/fricative	< 2.5 years	21	12.33	4.223	-1.239	45	0.222
	>/= 2.5 years	26	13.88	4.302			
Stop/nasal	< 2.5 years	21	9.95	2.519	-1.617	45	0.113
	>/= 2.5 years	26	11.04	2.088			
Stop/affricate	< 2.5 years	21	9.81	2.857	-.910	45	0.368
	>/= 2.5 years	26	10.54	2.626			
Aspiration	< 2.5 years	21	3.81	2.337	-1.255	45	0.216
	>/= 2.5 years	26	4.62	2.061			

Table 8: Mean, SD and t-test results according to better ear aided threshold.

Contrast	Better ear aided threshold	N	Mean	SD	t-value	df	Sig (2-tailed)
Stop/fricative	</= 45 dB HL	21	14.10	4.110	1.307	45	0.198
	> 45 dB HL	26	12.46	4.375			
Stop/nasal	</= 45 dB HL	21	11.10	2.234	1.451	45	0.154
	> 45 dB HL	26	10.12	2.355			
Stop/affricate	</= 45 dB HL	21	10.71	2.667	1.137	45	0.262
	> 45 dB HL	26	9.81	2.757			
Aspiration	</= 45 dB HL	21	4.95	2.012	2.015	45	0.050*
	> 45 dB HL	26	3.69	2.223			

Aided threshold of better ear

T-tests were also computed to compare the performance according to the aided threshold of the better ear, wherein participants were divided into two groups: aided threshold </= 45 dB HL (21 participants) and aided threshold > 45 dB HL (26 participants). Mean scores and SDs for each of the contrasts along with the results of the t tests computed to compare the performance of participants with better ear aided threshold of 45 dB HL or lower (better) and with thresholds greater (poorer) than 45 dB HL are shown in Table 8.

As can be seen from Table 8, the mean scores of participants with better ear aided threshold of 45 dB HL or lower are higher than those for participants with better ear aided threshold greater than 45 dB HL for all contrasts. The SD values are higher for participants with aided threshold greater than 45 dB HL for all contrasts. Independent Samples t-tests indicate a significant difference between the mean scores of participants with better ear aided threshold of 45 dB HL or lower and those with thresholds greater than 45 dB HL for only one of the contrasts: aspiration.

DISCUSSION

NH participants

Results indicate that the manner contrasts of stop vs. fricative and stop vs. nasal were consistently acquired by the NH participants in the present study, while the contrasts of stop vs. affricate and aspiration were yet to be fully acquired by the age of 8 years. Several studies have reported on the perceptual development of phonological features in normal hearing children and state that it is a long-lasting process that starts before the age of 1 year and ends during adolescence and is closely related to early exposure of different sounds from a specific language.[31, 32] Studies also state that the features that are significant to the linguistic environment are perceived with greater precision until the end of childhood or even adolescence.[8,33, 34]

Raja et al reported mean percentage scores of 86% in the auditory-alone condition and 92% in the auditory-visual condition for consonant contrasts in normal hearing children.[17] These results indicate that consonant contrasts as assessed using minimal pairs were not developed in these participants till the age of 12 years. However, the authors have not categorized the 30 stimuli assessing consonant contrasts according to manner, place or voicing.

CI participants

Among the consonant manner contrasts assessed in the present study, performance of CI participants was the best for stop vs. fricative, with stop vs. nasal and stop vs. affricate following closely and poorest performance for aspiration contrast. The average percentage scores for all the first three manner contrasts ranged between 80 and 87%, while that for aspiration was 64.88%.

Bergeson, Pisoni and Kirk reported on speech feature discrimination in deaf children with cochlear implantation through a retrospective analysis of results on the Minimal Pairs Test administered to children enrolled in a longitudinal study at the Indiana University School of Medicine.[23,36] All 36 children in the study were pre-lingually deaf, received an implant between 1 and 6 years of age and were followed for a period of seven years following implantation. Authors state that by 2 years' post-implant, most children achieved near-ceiling (around 80%) levels of discrimination performance for vowel height, vowel place, and consonant manner. The performance attained by the participants in the present study is similar for manner contrast identification. Aspiration is a feature which is not commonly reported in the reviewed literature, perhaps as this feature is not phonemic in the reported languages. In Marathi, aspirated sounds occur commonly and need to be contrasted with their unaspirated counterparts.

With reference to the age at implantation the 26 participants implanted at or before 4 years of age performed better than the 21 participants implanted after 4 years of age for all manner contrasts. Also, performance of participants implanted after 4 years showed greater variability. However, the difference in their scores was not statistically significant for most contrasts. Significant difference was obtained only for stop vs. nasal. Further, 28 participants who had used the device for more than 2.5 years performed better than the 19 participants who had used the CI for 2.5 years or less for all contrasts, though the differences in performance were not statistically significant.

Eisenberg et al reported improvement in performance on a preschool test battery over a period of one year for 42 children with cochlear implants with a mean age of 2.3 years at baseline.[24] Bergeson, Pisoni and Kirk reported results of retrospective analysis of performance of 36 participants tested over a span of 3 to 7 years and an average cochlear implant use of 4 years.[23] They reported consistent improvement in performance in speech feature discrimination for vowels and consonants, spoken word recognition and sentence comprehension over the duration of the study. All children in their study were implanted between 1.4 and 5.8 years of age. However, performance was not analysed with reference to age at implantation.

Dornan et al examined the speech perception, language development and speech of 25 children using hearing aids or cochlear implants attending an AVT program at baseline and after a period of 21 months.[27] They reported significant improvement in speech perception for live voice presentations, but not for recorded voice. Dowell et al assessed a group of 102 children with multi-channel cochlear implants for open-set speech perception abilities at six-monthly intervals to identify key factors that act as predictors of long term outcomes.[37] The sample consisted of a wide range and variety of variables such as age, age at onset of hearing loss, experience with implant use and communication modes. Multivariate analysis indicated that shorter duration of hearing loss, later onset of hearing loss, greater duration of implant use and oral/aural communication mode were the factors associated with better open-set speech perception performance. Of the variables that contributed directly to the variance in the performance were age at implantation or duration of implant use, but not both.

Sarant et al attempted to identify the common factors that influence speech perception scores in children with cochlear implants by collecting open-set speech perception data from 167 implanted children.[38] Among the main factors that significantly affected scores on all assessments was duration of deafness, which actually refers to age at implantation for children with congenital or pre-lingual hearing loss. Children with shorter durations of deafness demonstrated higher speech perception scores. The longer the duration of deafness, greater is the auditory deprivation, leading to long-lasting and in some cases reversible effects on the neural structures.

Harrison, Gordon and Mount reported results from two of their studies to determine if there is evidence for specific critical periods during development.[39] In the first study, they prospectively collected several speech perception outcome measures on 82 congenitally deaf children who had used their implants for a minimum of 5 years. The children were grouped into subsets according to age at implantation and were followed up to 8 years post implant. Their outcomes indicate that after long term implant use, children implanted at young ages perform better than those implanted at older ages. By 5 years post-implant, children implanted at or before 5 years of age outperformed their older peers in all phoneme and word perception tasks. They also reported that children implanted at 2 years of age appeared to exceed all other age groups and those implanted at older ages may not achieve speech perception levels obtained by those implanted younger even after long periods of implant use. In their second study the authors used an objective method to split the obtained datasets on the basis of age at implantation. The aim was to obtain the optimal split age, for which they performed binary partitioning analysis, which indicated that it is at age of implant (or duration of deprivation) of 8.4 years when the outcomes are maximally different.

In the present study, higher scores were obtained by children implanted at or before 4 years of age. The age of 4 years was used as the criterion in order to distribute the 47 participants fairly equally in the two groups. Findings such as those from Harrison, Gordon and Mount[39] could be one of the reasons why the differences in the scores were not statistically significant. Additionally, the number of subjects in each group was limited.

HA participants

Several studies have documented perception of speech features in individuals with sensori-neural hearing loss.[40-43] It is evident from the results of these studies that supra-segmental features are perceived better than segmental features, vowels are perceived better than consonants, vowel height is perceived better than vowel place and consonant voicing better than consonant place.

Plant and Plant and Westcott reported that many of the children with profound hearing impairment were able to utilize spectral cues in word identification while others appeared to be limited to time and intensity information.[44,45] Further, children with very similar audiometric configurations differed widely in their ability to perform this task. Children with profound hearing losses were, however, able to categorize words correctly according to their syllable number and type. The authors also report that most children, regardless of their average hearing loss, were able to differentiate reliably between CVC words which differed only in vowel duration, with some difficulty for the pair /I/ versus /i/. Almost all of the children with severe hearing impairment were able to discriminate between initial voiced and voiceless stop consonants in word pairs, while children with profound hearing impairment showed a lot of variability on this task.

For participants using hearing aids, Raja et al reported mean percentage scores of 54% in the auditory-alone condition and 71% in the auditory-visual condition for vowel contrasts and mean percentage scores of 52% in the auditory-alone condition and 69% in the auditory visual condition for consonant contrasts.[17] These findings indicate better performance for vowel contrasts as compared to consonant contrasts for children with HA. However, the authors have not categorized the 30 stimuli assessing consonant contrasts according to manner, place or voicing.

With reference to the age at fitting of amplification of HA participants, the 21 participants fitted with hearing aids before 2.5 years of age performed poorer than the 26 participants fitted at or after 2.5 years of age for all contrasts. However, the difference in their scores was not statistically significant for any of the contrasts. Further, 21 participants who had average better ear aided thresholds of 45 dB HL or better performed better on all contrasts than the 26 participants who had average better ear aided thresholds greater than 45 dB HL, with a statistically significant difference for aspiration contrast. The results with reference to age at fitting of hearing aid are difficult to explain, while those with reference to average aided threshold of better ear are as expected. Children having better aided thresholds are better able to access the various speech cues, enabling them to extract information pertinent to the various vowel and consonant contrasts such as those assessed in the present study.

Sininger, Grimes and Christensen aimed to determine the influence of factors such as age at fitting of amplification and degree of hearing loss on the listening outcomes in young children with bilateral sensori-neural hearing loss.[46] They longitudinally followed 44 infants and toddlers with mild to profound hearing loss and obtained measures of speech perception, speech production and spoken language. Results indicated largest influence of age at fitting of amplification followed by degree of hearing loss in the better ear, where children with lesser degrees of hearing loss and fitted with hearing aids early in life performed better. The results of the present study with reference to the age at fitting of hearing aids do not uphold these findings.

Comparison of three groups

Results indicate that the NH group performed significantly better as compared to CI and HA groups while CI group performed better than HA group on all the four manner contrasts. Bittencourt et al presented a systematic review of scientific papers with an objective to assess if cochlear implants provide more benefit than hearing aids in pre-lingually deaf patients.[47] They reviewed 12 studies spanning from 1994 to 2010, most of which included data on speech perception and acquisition. In general, all these studies demonstrated that cochlear implants were unquestionably more beneficial in speech perception development, linguistic development and social-emotional areas, when compared to conventional hearing aids. Several other studies have reported children with cochlear implants to perform better than those with hearing aids.[17,25,48,49]

Eisenberg et al conducted a longitudinal multicentre investigation to identify factors influencing spoken language in young children with cochlear implants and enrolled normal hearing peers as controls to obtain performance on a speech recognition test battery.[24] They reported that several children in the CI group approached performance levels comparable to those of NH peers for some early measures in one year after implantation. Raja et al.[17] reported significantly better performance in NH children as compared to those with CI and HA for vowel and consonant contrasts assessed using minimal pairs in Telugu. Performance of CI participants was significantly better than those with HA. Similar results were found in the present study.

CONCLUSION

Performance of NH group indicates that performance on manner contrasts such as stop vs. fricative, stop vs. nasal is consistent by the age of 8 years as all participants obtained ceiling scores on these contrasts. Stop vs. affricate contrast can be considered to be almost achieved as only one or two of the 106 participants provided erroneous responses. On the other hand, speech feature discrimination abilities are not fully developed for aspiration (93.88%). NH participants performed significantly better than participants with hearing impairment across all contrasts. Among participants with hearing impairment, CI children performed significantly better than children with HA on all contrasts. Some CI participants did obtain ceiling scores for some contrasts, but average performance of CI group did not reach ceiling performance. Performance of HA participants was more variable as compared to CI participants and they performed significantly poorer than the CI participants. Very few HA participants achieved ceiling scores on the various contrasts, and none scored at ceiling for stop vs. nasal contrast. Among participants with CI, those implanted at or before 4 years of age performed consistently better on all contrasts as compared to those implanted after 4 years of age, though significant difference was found for stop vs. nasal contrast. Participants using the CI for more than 2.5 years also performed consistently better than those using it for 2.5 years or less. Among participants with HA, children fitted at or after 2.5 years of age performed consistently better than those fitted before 2.5 years of age. Also, those participants whose average aided thresholds were 45 dB HL or lower (better) performed better than those with average aided thresholds above 45 dB HL.

Implications

Normative data on development of various aspects of speech perception in Marathi is generated from the data obtained on normal hearing children and implies that development of all aspects of manner contrast identification is not complete in normal hearing children by 8 years of age. Development of certain phoneme contrasts is achieved after 8 years of age. The results of the present study uphold the findings of several other studies which report that speech perception skills of children with normal hearing are better than those of children with cochlear implants and hearing aids. Also, children with cochlear implants have better speech perception skills than those using hearing aids. Results also imply and endorse the need for early fitting of amplification and early intervention in children with congenital hearing impairment.

Limitations

Participants over a limited age range were included in the study. No prior information is available about development of speech perception skills in Marathi children with and without hearing impairment. To obtain such information, it is important to include children over a wide age range, which was not done in the present study. Inclusion of younger as well as older children would have helped in establishing a clear developmental sequence for speech perception abilities. Participants with CI and HA were included in the study only when they fulfilled certain inclusion criteria. This led to a limited number of participants being available in these groups. Male-female differences were not studied for participants with and without hearing impairment. HA group included participants with severe to profound hearing loss. Children with different degrees of hearing loss were not included in the sample. While most participants in the HA group used digital hearing aids, some used trimmer digital or analog hearing aids. Any differences in performance due to the differences in hearing aid circuitry were not studied. The study assessed speech perception abilities using a closed-set paradigm, which has an inherent limitation of artificial boosting of scores due to guessing or chance responses. Scores of participants with hearing impairment could have been inflated due to chance responses..

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