Development and Evaluation of High frequency word identification test for children in Indian-English (HF-WITCIE)

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Abstract

The aim of the study was to develop a 'High frequency word identification test for children in Indian-English (HF-WITCIE)" and validate the same on typically developing children. Additionally, the study aimed to check the equivalency of the four lists of the tests and establish whether the age of the participants (6 to 9 years) had an effect on the scores of the test. The study also determined the utility of the test on children simulated to have high frequency hearing loss. The 'HF-WITCIE' was developed using high frequency phonemes (/i/, /e/, /j/, /r/, /l/, /t/, /t^h/, /s/, /f/, /?/ , /t?/). The four lists of the test had 25 words each. The developed test material was validated on 48 typically developing children aged 6 to 9 years (16 each in the age groups ≥ 6 to < 7 years, ≥ 7 to < 8 years, and ≥ 8 to < 9 years). The utility of the test was evaluated on 12 children simulated to have high frequency hearing loss (6 gradual sloping hearing loss & 6 sharply sloping hearing loss). The children in the three age groups performed similarly indicating no age effect. The four lists of the test were found to be equivalent for the word scores and phoneme scores. Significant differences were seen in the scores of the typically developing children when compared to those with simulated gradual sloping hearing loss and sharply sloping hearing loss. The study indicates that the developed test can be used to assess speech identification difficulties faced by children with high frequency hearing loss.

Key words: *High frequency hearing loss, speech identification, age effect*

Introduction

Hearing loss is considered to be the most prevalent congenital abnormality in newborns and is more than twice as prevalent other conditions that are screened for at birth, such as sickle cell disease, hypothyroidism, phynilketonuria, and galactosaemia (Finitzo & Crumley, 1999). Johnson, Tabangin, Meinzen-Derr, Cohen, and Greinwald (2016) noted that among the 2,867 children studied by them, 7.6% had high frequency sensorineural hearing loss. Also, as observed by le Clercq, van Ingen, Ruytjens, and van der Schroeff (2016) the prevalence of high-frequency hearing loss was found to be 9.3% after the exposure to loud music.

Ross (2009) reported that the most common type of hearing impairment is a high-frequency loss, resulting in individuals having difficulty in perceiving many high frequency unvoiced consonants such as the /t/, /k/, /f/ , /t^h/, /ʃ/, and /s/. Ineffective perception of stop consonants by those with high frequency hearing loss has also been reported (Dubno, Dirks, & Ellison, 1989). A study of simulated high frequency hearing loss revealed that place error confusion was seen to be more compared to manner cues and these errors were more in sharp high frequency sloping as compared to gradual high frequency sloping hearing loss (Geetha, Ashly, & Yathiraj, 2006; Kumar & Yathiraj, 2009). Further, it has been observed that noise has a deleterious effect on speech perception in those with sloping audiogram configuration (Cohen & Keith, 1976). Individuals with this type of problem were observed to often complain of hearing and not understanding. Besides resulting in difficulties in perception of high frequency speech sounds (Ahmed, Mourad, El-Banna, & Talaat, 2015; Pichora-Fuller & Souza, 2003), high frequency hearing loss has been noted to result in difficulty in adequate monitoring of fricative production (Stelmachowicz, Pittman, Hoover, Lewis, & Moeller, 2004).

Studies mainly report of high frequency hearing loss being present in adults (Gates & Mills, 2005; Peng, Tao, & Huang, 2007; Rabinowitz, Sircar, Tarabar, Galusha, & Slade, 2005; Thelin, Joseph, Davis, Baker, & Hosokawa, 1983). However, high frequency hearing loss has been found to be associated with otitis media after middle ear disease resolves and after middle ear dysfunction was excluded (Dieroff & Schuhmann, 1985; Hunter et al., 1996). Middle ear effusion has been reported to be a common problem in children (Alles et al., 2001; Hall-Stoodley et al., 2006; Tasker et al., 2002). Also, severe-to-profound high frequency hearing loss was reported to be prevalent in survivors of congenital diaphragmatic hernia (Robertson, Cheung, Haluschak, Elliott, & Leonard, 1998). It is well established that high levels of noise results in high frequency hearing loss. In the past exposure to high levels of noise was mainly associated with adults. However, due to the increasing availability of personal music players and mobile phone, the younger population is also susceptible to noise induced high frequency hearing loss (le Clercq et al., 2016; Shargorodsky, Curhan, Curhan, & Eavey,

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2010). The presence of high frequency hearing loss in children necessitates the availability of speech identification tests to identify their perceptual problems.

As reported in literature, generally used speech identification tests are not sensitive to detect the perceptual problems in those with high frequency hearing loss. Low frequency cues in such tests were reported to contribute redundant cues, leading to an under-estimation of perceptual difficulties of those with high frequency hearing loss (Chung & Mack, 1979; McDermott & Dean, 2000; Owens & Schubert, 1977). To detect the perceptual problems of those with high frequency hearing loss, many researchers have developed speech identification tests having a high concentration of high frequency speech sounds. A few of the existing high frequency speech identification tests developed in other countries include 'The Gardner High Frequency Word Lists' (Gardner, 1971), 'The Pascoe High Frequency Test' (Pascoe, 1975), 'The California Consonant test' (Owens & Schubert, 1977). Some of the high frequency word identification tests developed in Indian are 'High Frequency Speech Identification Test for Hindi and Urdu Speakers' (Ramachandra, 2001), 'High-Frequency Kannada Speech Identification Test' (Mascarenhas, 2002),'High Frequency-English Speech Identification Test' (Sudipta & Yathiraj, 2005-2006), 'High Frequency Speech Identification Test in Tamil'(Sinthiya & Sandeep, 2009), 'High Frequency Speech Identification Test in Telugu' (Ratnakar & Mamatha, 2009-2010) and 'High Frequency Speech Identification Test in Manipuri Language' (Hmangte & Geetha, 2014). These high frequency speech tests have been developed for adults and no tests are available for children. Thus, the aim of the study was to develop a high frequency speech identification test in Indian-English for children with high frequency hearing loss. The study also aimed to validate the developed test on normal hearing children, to check the equivalence of the different lists of the developed test, to evaluate the effect of age of children on the performance of the test, to confirm the utility of test material on simulated high frequency hearing loss. Additionally, the effect of location of testing (school premises & sound treated room set-up) on the test scores was also evaluated.

METHODS

The study was undertaken in three stages. Stage I involved the development of a 'High Frequency Word Identification test for children in Indian-English (HF-WITCIE). Stage II dealt with the validation of HF-WITCIE on typically developing children and Stage III involved validation of HF-WITCIE on children with hearing impairment. A standard comparison design was used to conduct the study.

Participants

Twenty typically developing children, aged 6 to 9 years, from different schools were selected to check the familiarity of the test material in Stage I. The developed test was validated on 48 typically developing children (16 each in the age groups ? 6 to < 7 years, ? 7 to < 8 years, and ? 8 to < 9 years) in Stage II. The utility of the test was established on 12 typically developing children aged 6 to 9 years, simulated to have high frequency hearing loss in Stage III of the study.

The participants for the study were selected using a purposive sampling technique. For Stages I, II and III of the study, children studying in English medium schools for at least 3 years were selected. They had hearing sensitivity within normal limits, with air conduction and bone conduction thresholds being within 15 dB HL, and the air-bone gap being not more than 10 dB HL. It was ensured that they had normal speech and language and no history of ear discharge. They were not selected if they had failed any class.

Instruments:

A calibrated audiometer (Inventis Piano) with headphones (TDH 39 with MX41/AR ear cushion) and with facility for audio input was used for testing the hearing abilities of the children as well as evaluating speech identification. An immittance audiometer (GSI-Tympstar) was used to rule out middle ear pathologies. The recorded material used in the study was presented from a computer loaded with Adobe Audition (Version 3.0) that was routed through the audiometer.

Test environment:

Audio recording of the test and part of the validation of the material was carried out in a sound treated double room. The ambient noise level in the test suite was as recommended by the American National Standards Institute (1999 -R2013). A part of the validation of the developed test was carried out within the premises of schools, in rooms that were quiet and distraction-free.

Procedure:

Stage I: *Development of the High Frequency Word Identification test for Children in Indian-English (HF-WITCIE)*

Initially, a list of monosyllabic words containing high frequency phonemes (Table 1) was selected from story books and text books that were appropriate for children aged 6 to 9 years. Only words having more than 50% high frequency phonemes and that were likely to be familiar to children were selected. The 150 words that were shortlisted were evaluated to determine whether they were familiar to children.

Table 1 : High frequency phonemes used for the construction of High Frequency Word Identification test for Children in Indian-English (HF-WITCIE)

Phoneme Class	Phonemes
Vowels	/i/, /e/
Semi vowels	/j/, /r/, /l/
Stops	/t/, /tʰ/
Fricatives	/s/, /f/, /ʃ/
Affricatives	/tʃ/

The familiarity of the monosyllabic words was tested on 20 children aged 6 years. The children were instructed to inform whether they knew the meaning of each word either verbally or through action. Based on the responses of the children, each word was classified as 'highly familiar', 'familiar', and 'not familiar'. Words that the children report that they had heard of and could describe / demonstrate the meaning were classified as 'highly familiar'. Words that they had heard of but did not know the meaning were classified as 'familiar'. The words were grouped as 'unfamiliar' if the children had neither heard of them nor knew the meaning.

The words that were categorised as 'highly familiar' or 'familiar' were utilized for the construction of final test. Four lists were constructed, with each list having 25 words. The word-lists were equated in terms of occurrence of different phonemes and level of familiarity. The developed test, 'High Frequency Word Identification Test for Children in Indian-English' (HF-WITCIE) was audio recorded before being further evaluated.

Audio recording of the test material was done by a female speaker who was fluent in Indian-English and had a neutral Indian accent. It was recorded in a sound treated room using a condenser microphone (B-2 PRO) with an audio interface (MOTU micro book II). The material was recorded on to a computer loaded with Adobe Audition (Version 3) using a sampling frequency of 44100 Hz and resolution of 32 bits. The recording was done with the microphone placed 6 inches from the mouth of the speaker. The microphone was placed on a stand at the level of her mouth. The mono recorded material was normalized to ensure that the average root mean square power of each word was within +/- 4dB from the mean value. A 1 kHz calibration tone having an intensity equal to the average root mean square value of the words was generated before each wordlist. A goodness test was performed on 5 adults, fluent in Indian-English, to establish whether the quality of the recording was acceptable. As all the words could be identified with ease, no further modification was done.

Further, the material was filtered to simulate high frequency hearing loss based on criteria given by Lloyd and Kaplan (1978). This was done by using Adobe Audition (Version 3.0). The attenuation at specific frequencies to simulate gradual and sharply sloping configurations of high frequency hearing loss is provided in Table 2.

The developed HF-WITCIE test was validated on 48 typically developing children who meet the participant selection criteria. Prior to evaluating each child, informed consent was obtained from the caregivers of the children, adhering to Ethical Guidelines for Bio-Behavioural Research Involving Human Subjects (2009) of All India Institute of Speech and Hearing.

Half the children were randomly selected and evaluated in the sound treated set-up and the other half were evaluated within the school premises. Those in the sound treated set-up, heard the stimuli played through a computer, the output of which was routed to through a diagnostic audiometer (Inventis Piano). The participants heard the test stimuli through headphones (TDH 39 with Mx41/AR ear cushion) at 40 dB SL (Ref. PTA). The 1 kHz calibration was used to adjust the VU meter deflection of the audiometer to zero.

Table 2 : Attenuation levels for simulating gradual and sharply sloping high frequency hearing loss

Frequency (Hz)	Attenuation (dB)	
	Gradually Falling configuration	Sharply Falling configuration
500	12.4	9.4
1000	3.4	-5.6
2000	-8.6	-19.9
4000	-16.1	-34.1

Stage II: Validation of HF-WITCIE on typically developing children

The children who were tested within the school set-up were evaluated using the computer loaded with Adobe Audition (Version 3) via headphones (TDH 39 with Mx41/AR ear cushion). Prior to testing the children, the volume control of the computer as well as that of the audio software were manipulated such that the output via the headphones was 70 dB SPL. It was set to this value as it was observed that the majority of the children tested in the sound-treated room had average pure-tone thresholds of 10 dB HL. This output level was set using the 1 kHz calibration tone for each list using a Larson Davis Sound level meter. The output was measured for the left and right headphone separately. The stimuli were played using Adobe Audition (Version 3) and the output was heard by the participants through headphones having noise excluding domes.

The word lists were randomised to avoid a list order effect. Further, the half the participants were tested in their left ear and the other half were tested in their right ear so as to avoid an ear effect. The participants were instructed to repeat and write the words heard by them.

Stage III: Validation of HF-WITCIE on children with *hearing impairment*

Twelve typically developing children were tested with the material that simulated high frequency hearing loss in Stage III. This was done as children with high frequency hearing loss were not available to check the utility of the developed test. Among the 12 children, 6 children were evaluated using the material that simulated gradual sloping configuration and the other 6 children with material that simulated sharply sloping configuration. The procedure used for evaluation was similar to that used in Stage II of the study.

Scoring:

Word as well as phoneme score were calculated for each list for each child. Every correctly identified word/ phoneme was given a score of one and an incorrectly identified word/phoneme was given a score of zero. The scores for each child for each list was tabulated. The maximum obtainable word score was 25 and maximum obtainable phoneme score was 59 for each list. The responses were scored in a similar manner in Stage II and Stage III of the study.

Statistical Analyses:

The raw scores of the participants were statistically analysed using Statistical Package for the Social Sciences (Version 17) software. Descriptive and inferential analyses were carried out. A Shapiro-Wilk test indicated that the data were not normally distributed. Hence, non-parametric statistics were used. A Mann Whitney-U test was used to determine the difference across the two set-ups (sound treated set-up & school set-up). A Friedman's test was used to determine the differences within the four lists developed. In order to check for an age effect on four lists, for both word scores and phoneme scores, a Kruskal-Wallis test was carried out. To compare the scoring procedures (word versus phoneme), Wilcoxon Signed Rank test was used.

RESULTS

The data obtained from all the participants for the four high frequency word-lists were analysed to determine the effect of the test location (school set-up & sound treated room set-up) and also the effect of age on the performance of the children. Additionally, inter-list equivalency and the effect of the scoring procedure (word score & phoneme score) were analysed. Analysis was also done to compare the performance of the normal hearing children with those of children listening to the test stimuli simulating high frequency hearing loss. The phoneme errors were also calculated for the children with normal hearing and simulated high frequency hearing loss. Cronbach's alpha was administered to check the test-retest reliability of the newly developed 'High frequency word identification test for children in Indian-English (HF-WITCIE)'.

Effect of test location (school & sound treated room set-up) on scores obtained on the test scores

The mean, standard deviation (SD) and median obtained for the scores of the HF-WITCIE in two different locations (school & sound treated room set-up), across the age groups is shown in the Table 3. This information is provided for both for word scores and phoneme scores. It can be observed that both word scores and phoneme scores are similar in the two locations (school & sound-treated room set-ups).

To determine if the scores obtained in the two locations were significantly different, Mann Whitney-U test was carried out. The results revealed that there was no significant difference in the test scores obtained in the two set-ups, with the z values ranging from -0.13 to -0.70 and $p > 0.05$. As there was no significant difference between the scores obtained by the children in the two locations, the data obtained in the school set-up and the sound treated set-up were combined for further analyses. The effect of age of the participants was determined with scores of the two locations combined.

Effect of age of children on the performance of the test.

Across the four age groups, the word as well as the phoneme scores were observed to be similar (Table 4). This was especially true for the mean scores. The median scores increased marginally with increase in age. To establish whether there exists a significant difference between the performances of the three age groups, Kruskal-Wallis was administered for each of the four lists. This was done separately for the word scores and the phoneme scores. The statistical test revealed no significant difference ($p > 0.05$) between the three age groups for each list, irrespective of the scoring procedure used.

Comparison of scores (word & phoneme scores) across the lists.

From Table 4 it can be observed that the scores obtained across the four lists were similar. It is evident for the word scores as well as phoneme scores, irrespective of the age of the participants. Likewise, there was only a marginal variation in the standard deviation across the four lists.

Friedman's test was administered to confirm the equivalence of the lists. This was done for the data obtained on the typically developing children as well as that of the simulated hearing loss. In the typically developing children, the results indicated that there was no significant difference within the four lists for the word scores [$\chi^2(48) = 3.75, p > 0.05$] and the phoneme scores [$\chi^2(48) = 2.77, p > 0.05$].

The analysis done with the data that simulated gradual hearing loss, revealed no significant difference between the four lists for the word scores [$\chi^2(6) = 2.02, p > 0.05$] and for the phoneme scores [$\chi^2(6) = 1.73, p > 0.05$].

Likewise, for the data simulating sharply sloping hearing loss, no significant difference was observed for the word scores [χ^2 (6) = 1.00, p > 0.05] and for the phoneme scores [χ^2 (6) = 0.15, p > 0.05].

Table 3 : Mean, Standard deviation (SD), and Median for school and sound treated room set-up across age groups for word and phoneme scores.

Age group (yrs)	Score type		School set-up				Sound-treated room set-up			
			List 1	List 2	List 3	List 4	List 1	List 2	List 3	List 4
6 to 7	Word Scores	Mean	23.37	23.12	23.37	23.50	23.50	23.25	23.375	23.87
		SD	0.91	0.64	0.91	0.75	0.92	0.70	0.70	0.64
		Median	24.00	23.00	23.00	23.00	23.50	23.00	24.00	24.00
	Phoneme Scores	Mean	57.37	56.62	57.12	57.12	57.37	57.12	57.50	57.62
		SD	0.91	1.59	1.24	1.12	1.18	0.83	0.92	0.91
		Median	58.00	57.00	57.00	57.00	57.50	57.00	57.50	58.00
7 to 8	Word Scores	Mean	23.00	23.00	23.37	23.75	23.25	23.12	23.25	23.37
		SD	0.75	0.75	0.74	0.88	1.38	0.64	1.03	0.74
		Median	23.00	23.00	23.50	23.50	24.00	23.00	23.00	23.00
	Phoneme Scores	Mean	56.87	57.12	57.37	57.75	57.00	56.87	57.12	57.25
		SD	0.99	0.83	0.74	0.88	1.77	0.83	0.99	0.88
		Median	57.00	57.00	57.50	57.50	58.00	57.00	57.00	57.50
8 to 9	Word Scores	Mean	23.50	23.50	23.87	23.12	23.25	23.62	23.00	23.37
		SD	0.75	0.75	1.12	0.83	0.88	0.91	1.19	0.91
		Median	23.00	23.00	24.00	23.00	23.00	23.00	23.00	23.00
	Phoneme Scores	Mean	57.50	57.12	57.75	57.00	57.00	57.50	56.87	57.25
		SD	0.99	0.99	1.16	0.75	1.41	1.06	1.35	1.16
		Median	57.00	57.00	57.50	57.00	57.00	57.00	57.50	57.50

Note. Maximum possible word score = 25; Maximum possible phoneme score = 59

Table 4 : List-wise mean, standard deviation (SD) and median for word scores and phoneme score for HF-WITCIE for each age group and age groups combined.

Age groups (yrs)		Word Scores				Phoneme Scores			
		List 1	List 2	List 3	List 4	List 1	List 2	List 3	List 4
6 to 7	**Mean**	23.44	23.19	23.56	23.69	57.38	56.88	57.31	57.38
	SD	0.86	0.63	0.78	0.68	0.99	1.21	1.04	0.99
	Median	24.00	23.00	23.50	24.00	58.00	57.00	57.00	57.50
7 to 8	**Mean**	23.13	23.06	23.31	23.56	56.94	57	57.25	57.50
	SD	1.05	0.65	0.84	0.78	1.34	0.79	0.82	0.86
	Median	23.00	23.00	23.00	23.50	57.00	57.00	57.00	57.5
8 to 9	**Mean**	23.38	23.56	23.43	23.25	57.50	57.31	57.31	57.12
	SD	0.78	0.78	1.17	0.82	1.08	0.98	1.26	0.92
	Median	23.00	23.00	24.00	23.00	57.00	57.00	57.50	57.00
6 to 9	**Mean**	23.31	23.27	23.43	23.50	57.18	57.06	57.29	57.33
	SD	0.92	0.73	0.96	0.79	1.17	1.03	10.7	0.95
	Median	23.00	23.00	23.50	23.00	57.00	57.00	57.00	57.00

Note. Maximum possible word score = 25; Maximum possible phoneme score = 59

Comparison between the scoring procedures (word & phoneme scores).

As the maximum words scores (25) and phonemes scores (59) were different, the responses obtained from the participants were converted into percentage to the comparison of the two scoring procedures. In the typically developing children, the mean and median percentage word score was 93% and mean phoneme score was 97% (Table 5). Thus, it can be observed that the word scores were poorer than that of the phoneme scores. The significance difference between word scoring and phoneme scoring procedure was checked using Wilcoxon Signed Rank test. The results revealed that there was no significant difference seen for normal hearing participants for both scoring procedure ($z = -5.96$, $p > 0.05$, two-tailed).

The mean and median for word scores (71%) and phoneme scores (85%) for the gradual sloping hearing loss was found to be higher than the scores obtained by those with simulated sharply sloping hearing loss (65% & 77%, respectively), as shown in Table 5. Also, when the comparison was done for scores obtained by those with simulated hearing loss, there was a significant difference seen between the two scoring procedures for gradual sloping hearing loss ($z = -2.32$, $p < 0.05$, two-tailed) as well as for sharply sloping hearing loss ($z = -2.21$, $p < 0.05$, two-tailed). Thus, the phoneme scores were significantly higher than the word scores for both gradual and sharply sloping simulated hearing loss.

Comparison of the performance across individuals with normal hearing and simulated hearing impairment.

As can be noted from Table 5 and Figure 1, the scores were poorest for the simulated sharply sloping hearing loss group followed by the simulated gradual sloping hearing loss. The normal hearing listeners obtained the best scores. To check the significance difference between the performance of the three participant groups for the word scores and phoneme scores, Kruskal-Wallis test was carried out. The test results revealed that there was a significant difference between the performance of the three groups on the test for all the four lists for both word scores and phoneme scores ($p = < 0.05$).

As the Kruskal-Wallis test indicated that there was a significant difference between the three participant groups, Mann Whitney-U test was administered to check which of the group were significantly different from each other. This was done each of the four lists. There was significant difference seen between all pairs of groups (normal hearing listeners vs simulated gradual sloping hearing loss; normal hearing listeners vs simulated sharply sloping hearing loss; and simulated gradual sloping hearing loss vs simulated sharply sloping hearing loss). This was observed for both word scores and phoneme scores (Table 6).

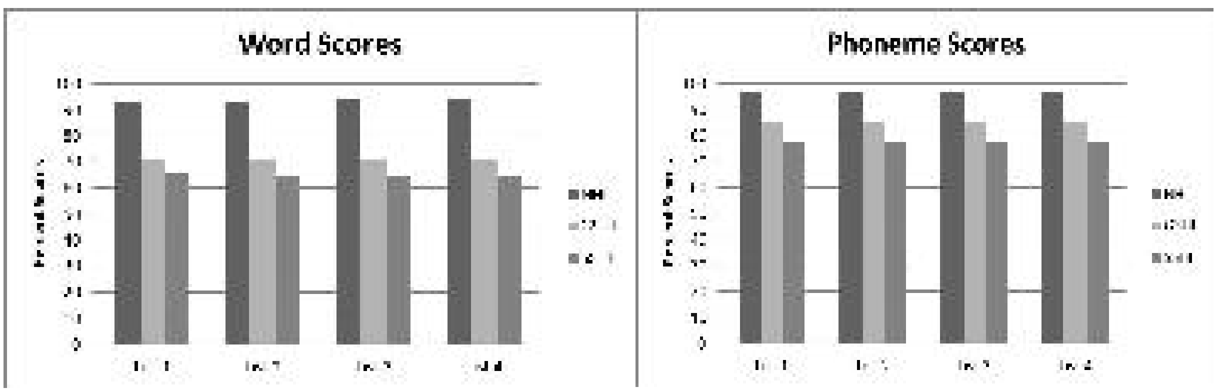

Figure 1: Mean word and phoneme scores for all three participant groups (NHL = Normal hearing listeners; GSHL = gradual sloping hearing loss; SSHL = Sharply sloping hearing loss).

Phoneme errors

To determine the errors in phoneme perception, initially percentages of the frequency of occurrence for all the phonemes were calculated. Later, using the formula given below the percentage of errors calculated.

$$Percentage\ of\ error = \left(\frac{No\ of\ errors\ observed\ for\ particular\ phoneme}{Frequency\ occurrence\ of\ phoneme \times Total\ number\ of\ childer} \right) \times 100$$

This was calculated separately for each of the three participant groups (normal hearing listeners, simulated gradually sloping & simulated sharply sloping high frequency hearing loss). Additionally, the percentage of phoneme errors were calculated separately for the high frequency phonemes (/i/. /e/, /j/, /r/, /l/, /s/, /?/, /t/, /th/, /f/, /t?/) and the low frequency phonemes (/?/, /u/, /b/, /g/, /w/, /k/, /m/, /n/, /h/, /d/, /p/), as shown in Table 7. While the high frequency speech sounds constituted of 71% of the phonemes in the test, the low frequency speech sounds constituted 29%. From the Table 7 it is observed that there were more errors were seen for the high frequency phonemes compared to the low frequency phonemes for all the three participants group. While most of the participants, substituted a high frequency phoneme with other phonemes, a few participants had addition errors and omission errors. Examples of the addition errors included the addition of the phoneme /h/ such that the word 'art' was identified as 'heart', and 'ear' as 'hear', as well as /th/ was added to the word 'tea' and identified as 'teeth'. Examples of omission errors included the deletion of the phonemes /f/ and /t/ such that the word 'fear' was identified as 'ear' and 'tent' as 'ten'.

Table 5 : Mean, Standard deviation (SD), and Median across three groups (normal hearing listeners, simulated gradual sloping hearing loss and simulated sharply sloping hearing loss)

		Word Scores					Phoneme Scores				
		List 1	List 2	List 3	List 4	Total	List 1	List 2	List 3	List 4	Total
Normal hearing	Mean	23.31 (93%)	23.27 (93%)	23.43 (94%)	23.50 (94%)	23.37 (93%)	57.18 (97%)	57.06 (97%)	57.29 (97%)	57.33 (97%)	57.21 (97%)
	SD	0.92	0.73	0.96	0.79	0.90	1.17	1.03	1.07	0.95	1.05
	Median	23.00 (93%)	23.00 (93%)	23.50 (94%)	23.00 (93%)	23.12 (93%)	57.00 (97%)	57.00 (97%)	57.00 (97%)	57.00 (97%)	57.00 (97%)
Gradual sloping	Mean	17.66 (71%)	17.66 (71%)	18.00 (72%)	18.00 (72%)	17.83 (71%)	50.16 (85%)	50.50 (86%)	50.33 (85%)	50.50 (86%)	50.37 (85%)
	SD	0.47	0.74	0.57	0.57	0.62	0.68	0.76	0.94	0.95	0.9
	Median	18.00 (71%)	17.50 (70%)	18.00 (71%)	18.00 (71%)	17.87 (71%)	50.00 (85%)	50.00 (85%)	50.00 (85%)	50.50 (86%)	50.12 (85%)
Sharply sloping	Mean	16.50 (66%)	16.16 (65%)	16.16 (65%)	16.16 (65%)	16.24 (65%)	45.33 (77%)	45.33 (77%)	45.50 (77%)	45.16 (77%)	45.33 (77%)
	SD	0.95	0.68	0.37	0.89	0.85	1.37	0.47	1.70	1.57	1.35
	Median	16.50 (66%)	16.00 (64%)	16.00 (64%)	16.50 (66%)	16.25 (65%)	45.00 (76%)	45.00 (76%)	45.50 (77%)	45.00 (76%)	45.12 (77%)
Gradual + Sharply sloping	Mean	17.08 (68%)	16.91 (68%)	17.08 (68%)	17.08 (68%)	17.03 (68%)	47.75 (81%)	47.91 (81%)	47.91 (81%)	47.83 (81%)	47.78 (81%)
	SD	0.95	1.03	1.03	1.18	1.10	2.64	2.66	2.78	2.96	2.99
	Median	17.00 (68%)	17.00 (68%)	17.00 (68%)	17.00 (68%)	17.00 (68%)	48.50 (82%)	48.00 (81%)	48.50 (82%)	48.00 (81%)	48.25 (81%)

Note. Maximum possible score for words = 25; Maximum possible score for phonemes = 59

Table 6. : Pairwise comparison and level of significance of difference across three groups for four lists on word scores and phoneme scores

	Word Scores				Phoneme Scores			
	List 1 *z* value	List 2 *z* value	List 3 *z* value	List 4 *z* value	List 1 *z* value	List 2 *z* value	List 3 *z* value	List 4 *z* value
NHL & GSHL	-4.11**	-4.30**	-4.10**	-4.17**	-4.10**	-4.13**	-4.08**	-4.09**
NHL & SSHL	-4.11**	-4.30**	-4.10**	-4.17**	-4.10**	-4.12**	-4.08**	-4.09**
GSHL & SSHL	-2.04**	-2.51**	-2.97**	-2.75**	-2.92**	-2.99**	-2.90**	-2.93**

*Note. NHL = Normal hearing listeners; GSHL = Gradual sloping hearing loss; SSHL = Sharply sloping hearing loss; ** $p < 0.05$*

Test-retest reliability

Test-retest reliability was done using Cronbach's alpha test for 6 typically developing children (2 in each age group) and 1 child from each of the two simulated sloping hearing loss groups. The test-retest reliability was high ($\alpha > 0.99$) for all the three age groups and hearing ability groups.

From the findings of the study, it was seen that there was no significant difference in performance, irrespective whether the children were tested in school or in a sound-treated facility. No significant difference was seen between the three age groups of children. Further, the four lists that were developed were found to be equivalent in all the participant groups who were evaluated. Thus, the lists may be used interchangeably. Significant differences were seen between word and phoneme scores, indicating that the information obtained from the two scoring procedures were not identical. Further, significant differences were seen between the normal hearing and gradual sloping hearing loss as well as sharply sloping hearing loss. The phoneme errors varied depending on the hearing status of the children. Also, the test was found to yield reliable test-retest scores.

DISCUSSION

The results of the newly developed 'High frequency word identification test for children in Indian-English (HF-WITCIE)', evaluated on 48 typically developing children and 12 children simulated to have hearing loss, are discussed with reference to the variables studied. The discussion is in terms of the effect of test location (school & sound treated room set-up) on the scores obtained; the effect of age of the participants on the performance of the test; equivalency of the four lists of the test; comparison between the scoring procedures (word score & phoneme score); and the performance of children simulated to have high frequency hearing

Table 7 : Percentage of high and low frequency phoneme errors in the normal hearing listeners and simulated high frequency hearing loss listeners.

	Phonemes	Participant groups			
		Normal Hearing (N = 48) (% error)	**Gradual sloping (N = 6) (% error)**	**Sharply sloping (N = 6) (% error)**	**Gradual + Sharply sloping hearing loss (N = 12) (% error)**
High frequency phonemes	/i/	2	33	38	36
	/e/	7	40	53	61
	/j/	0	48	50	54
	/r/	4	61	77	83
	/l/	2	33	33	34
	/t/	5	13	14	14
	/tʰ/	6	22	39	30
	/s/	5	23	57	40
	/f/	8	26	92	60
	/ʃ/	3	25	61	43
	/tʃ/	6	61	77	83
Low frequency Phonemes	/ɔ/	0	8	9	11
	/u/	1	7	11	10
	/b/	1	8	9	10
	/w/	1	3	5	6
	/k/	0	11	13	15
	/m/	0	7	9	11
	/n/	0	9	10	14
	/h/	2	9	12	13
	/d/	2	10	15	14
	/p/	3	9	13	11

loss (gradual sloping hearing loss listeners & sharply sloping hearing loss listener). Additionally, the phoneme errors made by the three groups of children (normal hearing, simulated gradual sloping hearing loss, & simulated sharply sloping hearing loss) are discussed.

Effect of test location (school set-up & sound treated room set-up) on scores obtained on the test scores.

The results of the 48 typically developing children indicated that no significant difference was seen in the performance of the test when administered in the school premises and in an acoustically sound-treated room. In literature, it has been recommended that speech identification testing should be carried out in sound-treated facilities (Bamford et al., 2007; Margolis & Madsen, 2015). However, the findings of the current study indicate that similar performance, as seen in a sound-treated facility, are possible if adequate precautions are taken when testing in non-sound-treated rooms. In the present study, while evaluating the children within the school premises, caution was taken to ensure that the noise levels within and around the room was low. Additionally, the use of noise excluding domes in the headphones must have further attenuated any noise present in the environment. Thus, when speech stimuli are presented at supra-threshold levels (70 dB SPL), in a quiet room using noise excluding domes, results similar to what is seen in a sound-treated room can be expected. Under these conditions, noise in the environment will not have much influence. Thus, from the results on location of evaluation it can be recommended that the testing can also be carried out within a school, provided necessary measures are taken to minimise the adverse effects of environmental noise while evaluating children.

Effect of age of children on the performance of the test.

The findings of the current study revealed that the three age group studied (≥ 6 to < 7 years, ≥7 to < 8 years, and ≥ 8 to < 9 years) performed in similar manner on the four lists of HF-WITCIE. This indicates that the four lists of the newly developed test can be used for individuals above the age of 6 years who have had at least 3 years of education in an English medium school. No age effect was probably seen as the familiarity of the test stimuli was established on the lowest age group studied (6 years olds). Thus, the words used for constructing the test material would have been familiar to all the age groups studied, resulting in no age effect.

Comparison of scores (word & phoneme scores) across the 4 lists of HF-WITCIE.

The analysis done to check the equivalency of the four lists of HF-WITCIE revealed that there was no significant difference seen across the four lists for all the three participant groups (normal hearing listeners, simulated gradual sloping hearing loss listeners, & sharply sloping hearing loss listeners). The equivalence between the four lists was observed for word scores as well as phoneme scores. The measures taken while constructing the four lists, to ensure that they are equal, would have resulted in them being equivalent. During the construction of the test, the word-lists were equated in terms of occurrence of different phonemes and the level of familiarity. This would have contributed to the lists resulting in equal performance in normal hearing as well as those with simulated hearing loss.

In literature, the need for equivalent lists has been recommended as they avoid familiarity of the stimuli influencing responses when evaluating individuals repeatedly. Multiple lists are required while selecting listening devices (Killion, Niquette, Gudmundsen, Revit, & Banerjee, 2004) or while check the impact of any rehabilitation procedure (Wang, Wu, & Kirk, 2010). Thus, the newly developed HF-WITCIE can be used while selecting listening devices for individuals with high frequency hearing loss above the age of 6 years as well as for evaluating the impact of any form of listening training.

Comparison between word and phoneme scores.

In the normal hearing participants, no significant difference was found between word and phoneme scores. This occurred due a ceiling effect where the children obtained near perfect scores. It was noted that standard deviation was only marginally higher for phoneme scores compared to the word scores. Similar results were seen by Mascarenhas (2002) and Sudipta and Yathiraj (2005-2006) for their normal hearing groups.

Unlike what was observed in the normal hearing participants in the present study, there was a significant difference seen in word and phoneme score for the simulated high frequency hearing loss listeners. The word scores were noted to be poorer than the phoneme scores for both gradual and sharply sloping hearing loss listeners. This occurred as a phoneme error within a word resulted in the entire word being scored wrong. However, the same error resulted in only one among the three or four phonemes on the word being marked wrong. This result is in agreement with the findings of Dillon, Ching, Plant, and Spens (1995), Mascarenhas (2002) & Sudipta and Yathiraj (2005-2006).

Depending on the purpose of running the newly developed test, either only word score requires to be calculated or both forms of scoring could be used. If the purpose of evaluation is to get an overall idea of the perceptual difficulties of an individual, then calculation of only word score is adequate. However, if the purpose of evaluation is to determine the specific perceptual difficulties of the individual to plan auditory listening training, the phoneme score would be preferred.

Comparison of the performance of the test across Individuals with normal hearing and Individuals with hearing impairment

The comparison between the performance of the normal hearing listeners and the two groups of simulated high frequency hearing loss participants (gradual sloping hearing loss & sharply sloping hearing loss) revealed that there was a significant difference across the three groups. The normal hearing listeners had significantly better scores compared to the simulated gradually sloping hearing loss listeners. The group simulating sharply sloping hearing loss had the poorest scores. This was observed for the word as well as the phoneme scores. The findings of the study indicate that the newly developed test is sensitive to the perceptual errors observed in individuals with high frequency hearing loss.

The sensitivity of the high frequency test can further be observed from the difference in phoneme errors seen across the three participant groups. In the simulated high frequency hearing loss participants, all the high frequency phonemes were affected. Furthermore, the numbers of errors seen per phoneme were more in those with simulated hearing loss compared to the normal hearing listeners. On the contrary, the percentage of errors for the low frequency speech sounds were markedly low for all three groups, with it being similar in the two sloping hearing loss groups. Further, the maximum errors seen for two groups combined were for /r/, /t?/ followed by /e/, /f/, /j/ ,/l/, /ʃ/, /s/,/e/,/th/, and least error was seen for phoneme /t/. This trend was seen for both those with simulated gradual and sharply sloping hearing loss.

Studies on individuals having high frequency hearing loss have indicated that the speech sounds that they mainly have difficulty in include /t/,/k/,/f/, /th/, /s/ and /ʃ/ (Dubno et al., 1989; Ross, 2009). Fricative perception were found to be more affected in simulated audiogram configuration than other manner of articulation, as reported by Kumar and Yathiraj (2009). Owens, Benedict, and Schubert (1972) also reported that /s/, /ʃ/ and /t/ were more often affected by individuals with sharply sloping hearing loss than individuals with flat hearing loss.

In the present study, more errors were seen for the phonemes /t/, /f/,/th/,/s/ and /?/ in those with a simulated high frequency hearing loss. These findings are similar to that of Dubno et al. (1989). Also, the findings that fricatives are more affected and /s/, /ʃ/ are markedly affected in sharply sloping hearing loss, are in agreement with studies reported in literature (Kumar & Yathiraj, 2009; Owens et al., 1972).

CONCLUSIONS

The findings of the study indicate that the newly developed test is sensitive to detecting the perceptual difficulties seen in individuals high frequency hearing loss. The test is also sensitive to differentiating the perceptual difficulties faced by individuals with high frequency hearing loss having varying steepness. As the four lists of the test were found to be equivalent in all the participant groups who were evaluated, they may be used interchangeably. The test can be administered either in a quiet room within a school or in a sound-treated facility. The significant differences between word and phoneme scores indicate that the two scoring procedures were not identical. The test was found to yield reliable test-retest scores.

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