Efficacy of a Hearing Checklist and Screening Test in Identifying Hearing Problems in Primary School Children

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Abstract

The study evaluated the sensitivity, specificity as well as the positive and negative predictive values of a hearing screening checklist and a screening test developed using the Ling's 6-sound test. Hundred and fifty-four primary school children, aged 5 to 7 years, were screened and later tested on standard audiological tests (diagnostic pure-tone audiometry, tympanometry, acoustic reflex test & DPOAE). The screening checklist 'Signs and symptoms of hearing loss' was found not to be effective in detecting the presence of hearing impairment. The recorded 'Ling 6-sound screening test' was found to be a better predictor of the presence of hearing loss compared to the screening checklist as it had a higher sensitivity and specificity. The screening test also had relatively low over referral and under referral rates when compared to the checklist. The combination of the checklist and the screening test did not give rise to significant improvement in the effectiveness of the screening program. Hence, the use of the Ling's 6 sound screening test in isolation is recommended.

Keywords: *School screening test, symptoms of hearing loss, sensitivity, specificity.*

Introduction

Hearing is known to play a vital role in the acquisition of speech and language as well as in the achievement of other developmental milestones in young children. Undetected hearing impairment, especially in children, has been found to cause lifelong disturbance in social, emotional, behavioural and cognitive spheres or combination of any of them (Yoshinaga-Itano, Sedey, Coulter & Mehl, 1998; Yoshinaga-Itano, 2003). Undetected hearing loss has also been found to negatively impact the educational achievement of children (Nix, 1977; Northcott, 1972; Maxon & Brackett, 1981).

The prevalence of hearing loss in school-age population was found to be 11.3% by Bess, Dodd-Murphy and Parker (1998). The study also reported that 9.62% to 12% of school-going children were at-risk for hearing loss. In another study by Olusanya (2001), the prevalence of hearing loss was found to be 13.9 % out of which 3.3 % was sensorineural hearing loss. In Mysore city of India, Nikam and Dharamraj (1971) found the incidence of hearing loss to be 3.9% in children aged 2 to 14 years. Further, the report of the National Sample Survey Organisation (NSSO), Government of India (1991), showed that the prevalence of hearing impairment in the age group of 0 to 14 years was 2.7% in rural India and 3% in urban India. An increase in the prevalence of hearing impairment was reported by NSSO (2002), where it was found to be 4.23% and 4.06% for rural and urban area respectively. The Human Development report of 1999, estimated a 0.3 million hearing impaired population between the ages of 0 to 4 years and 1.5 million in the age range of 5 to 12 years in India.

A major concern regarding hearing loss in children is that, in many cases it is identified only at a later stage based on symptoms. By this time the long term consequences of hearing loss have been noted to have already occurred (Nozza, Sabo & Mandel, 1997). Therefore it is important to detect the presence of it as early as possible for better intervention. In order to identify hearing impairment early, hearing screening has been recommended. The practice of hearing screening programmes in schools has been reported to have started in the 1920s but became a routine part only by 1960s (Northern & Downs, 2002). Harford, Bess, Bluestone and Klein (1978) described hearing screening as rapid and simple measures that identify those individuals who have a high possibility of a disorder which may otherwise go undetected. According to Alpiner (1976), hearing screening programmes include early identification of children through audiological screening and medical evaluation. Based on this, further recommendations for rehabilitation and periodic follow-up evaluation were made. Such a program was also noted to enable awareness about prevention of hearing loss, planning for appropriate rehabilitation and educational programmes for children with significant amount of hearing loss.

Due to the negative impact of hearing impairment, it should be mandatory to run hearing screening programmes routinely among school-age population with the best available and suitable tools and tests. Teachers can be the key persons to the whole process. Training them with a suitable screening test may enable early identification of such population.

The use of only checklists in identifying hearing problems in school children has been noted to have low sensitivity (Curry, 1950; Kumar & D'Mello, 2006). Hence, the tests such as pure-tone hearing screening have been used extensively (Glorig & House, 1957; Norton & Lux, 1960; FitzZaland & Zink, 1984; ASHA, 1997;

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Niskar, et al.,1998; Sarafraz & Ahmadi, 2009). However, it has been observed, that pure-tones are novel stimuli, which children are not exposed to. Martin (1991) reported that this has resulted in children finding them difficult to respond, thus increasing the false positives. On account of this difficulty, the addition of objective measures such as immittance audiometry has been advocated for school screening (Paradise & Smith, 1979; Krueger & Ferguson, 2002; Lewis, Dugdale, Canty & Jerger, 1975; FitzZaland & Zink 1984). This addition was found to improve the sensitivity (Krueger & Ferguson, 2002; Lewis et al., 1975). However, this would increase the cost of school screening considerably. In view of these issues, in addition to using checklists it is necessary to use a comprehensive screening test that can be used easily without the need for expensive specialized equipment. Thus, in a country like India, there is a need for effective, quick, simple and cost effective school screening procedures, due to the large population.

Speech materials as screening tool have not been advocated due to its negative effects (Ritchie & Merklein, 1972). Mencher and McCulloch (1970) attributed this to the audibility of some high intensity phonemes in some words which could act as cue in a few frequencies in children with mild hearing loss. However, this can be overcome with the use of selected speech sounds covering the speech spectrum and recorded to control intensity variations. Therefore, the use of speech sounds as a school screening procedure should be considered, especially since they are familiar to children.

The importance of hearing screening in India is documented in the 'Persons with Disabilities (Equal opportunities, Protection of Right and Full Participation) Act' (1995). The Act stipulates the necessity for early identification and intervention. Further, the National Programme in Prevention and Control of Deafness strongly promotes early identify hearing impairment in children. In order to carry out such a task, it is essential to have a cost effective as well as time effective hearing screening procedure that can be easily used in any part of the country. It is also important to study the effectiveness of such a screening procedure. Thus, the present study aimed to check the sensitivity and specificity of a hearing screening checklist and a pre-recorded hearing screening test when administered alone and when combined.

Method

The study was conducted in three phases. Phase-I involved the administration of a checklist 'Signs and Symptoms of Hearing loss' by the class teachers; Phase-II involved screening children with a recorded version of the Ling's 6-sound hearing screening test; and Phase-III involved running standard hearing screening tests and a diagnostic test.

Participants

One hundred and fifty-four primary school children aged 5 to 7 years from 5 schools were evaluated. Children studying in Grade-I or Grade-II were selected randomly for the study. Among the participants, 94 were from Kannada medium schools and 60 were from English medium schools. All the children spoke Kannada or English fluently. None of the children had any articulation problem and all of them were able to clearly produce the Ling's speech sounds (/a/, /i/, /u/, /m/, /s/ and /sh/), as reported by the teacher. On the day of the screening none of the children had any illness.

Further, 10 school teachers who taught the participants, were required to provide information regarding the hearing abilities of the children. Only those teachers, who had taught the children for 6 months or more, provided this information.

Material:

Two different school screening material were used to determined their sensitivity and specificity. The hearing checklist 'Signs and Symptoms of Hearing loss' developed in the Department of Audiology, All India Institute of Speech and Hearing, Mysore, was used to obtain the responses from the class teacher regarding their opinion about the hearing abilities of the children. A recorded version of the 'Ling's-6 sound test', which was done as a part of the present study, served as the second screening procedure.

Recording of the Ling's-6 sound test: The material was recorded by a female volunteer having clear speech and normal fundamental frequency. The recording was done using a sampling rate of 44.1 kHz and 32-bit analogue-to-digital converter in an acoustically treated room. Praat (version: 5.1.31) software was used for the recording. A unidirectional microphone (Ahuja AUD 101XLR) was placed at a distance of 6 inches from the mouth of the speaker. The recorded material was later edited and scaled using Adobe Audition (Version: 1.5) software to ensure that the intensity of all sounds were at the same level.

A goodness test was run on 10 adults to confirm the quality of the recorded material. The recording was redone until it was confirmed by all 10 adults that each of the recorded speech sounds was intelligible and not distorted. Six different lists were made by randomizing the order of the 6 speech sounds. A 1 kHz calibration tone was added prior to each of the lists.

Further, a pilot study was done to determine the intensity level at which the stimuli should be played in an

environment that simulated the noise levels of a typical quiet classroom. Prior to the pilot study, the output level of the recorded material from a laptop was determined using a sound level meter (Larson Davis 824) in a sound treated room. The volume control of the audio software and the computer were manipulated so that the output level through TDH-39 headphones was 25 dB HL and 30 dB HL. These levels were measured using an artificial ear (IEC318 Compliant Artificial Ear Coupler: Model AEC 101) with a 1 inch precision pressure response microphone (Model 2575). The control settings in the computer and the software for each of these intensity levels were noted. All the 10 adults and 10 children who participated in the pilot study could identify all six stimuli at 30 dB HL. However, only 40% of the adults and 20% of the children could identify the stimuli at 25 dB HL. They were able to identify the signals in an environment that simulated a quiet classroom, with activities going on outside. Based on these findings, it was decided that the screening should be done at 30 dB HL.

Test Environment

All the screening and diagnostic tests were done in quiet, well-lit rooms in schools. The rooms were large enough to accommodate the children and the examiners. The doors and windows were kept close to reduce the disturbance of noise emanating from outside the classroom. Sources of noise within the classroom, such as the CPU of a computer, fan, and other noise sources were switched off to ensure minimum noise interference. The ambient noise levels were such that a correction factor of not more than 15 dB had to be applied during testing. The thresholds of 3 normal hearing individuals, whose hearing thresholds had been earlier determined in a sound treated room that met the specification of ANSI S3. 1 (1991), were used for the biological calibration daily. Additionally, it was ensured that in each environment, Distortion Product Oto-Acoustic Emissions (DPOAEs) could be measured on all 3 normal hearing individuals, and that they could identify all the six stimuli of the recorded Ling's 6-sound test, when played at 30 dB HL.

Instrumentation

A calibrated diagnostic audiometer (Maico MA- 53) coupled with TDH-39 headphone and B-71 bone vibrator was used to estimate the pure-tone thresholds. Noise-excluding audio cups were used with the headphones. A calibrated middle ear analyzer (Interacoustics Titan) was used to carry out immittance tests. DPOAEs were evaluated using a calibrated OAE analyzer (GSI AUDIOscreener).

Procedure

As mentioned earlier, the study was conducted in three phases. The audiologist who evaluated the children during Phase-II, was blind to the findings of Phase-I. Similarly, a second audiologist who ran the standard screening tests and the diagnostic test was blind to the findings of Phase-I and Phase-II.

Phase-I: The school teachers were instructed to answer the questionnaire 'Signs and Symptoms of Hearing Loss' regarding the children in their class. Their doubts regarding the questionnaire were clarified in English or Kannada depending on the medium of instruction of the school. Children with a positive response on any of the questions of the checklist were categorised as 'refer' and those with no were categorised as 'pass'.

Phase-II: All the children who were administered the hearing checklist were also screened using the recorded Ling's 6-sound test in a quiet room. The test was played using Adobe Audition (version 1.5), with the volume controls of the software and the computer set such that the output from the TDH-39 earphones were 30 dB HL. Prior to placing the headphone on the children, they were seated comfortably and were instructed to repeat the speech sounds heard by them in each ear. Both ears of the children were tested independently using 2 of the 6 different lists of the Ling's 6-sound test. The screening was done first in the right ear for half the children and in the left for the other half to avoid any ear order effect. Children who could repeat all the sounds correctly were categorised as 'pass' and those who could not repeat one or more speech sounds were categorised as 'refer'.

Phase-III: All the children, both those who were marked 'pass' and 'refer', were later tested using standard screening tests. The standard screening tests consisted of immittance audiometry and DPOAE. Diagnostic pure-tone audiometry was also done to confirm whether the children had normal hearing thresholds.

Immittance evaluation was carried out for both ears of all the children. Tympanograms were obtained using standard 226 Hz probe tone and pressure sweep between +200 to -400 daPa. Ipsilateral acoustic reflex was recorded at 1000 Hz at 100 dB SPL. Those with 'A', 'As' and 'Ad' type tympanogram and reflex present were considered to be normal. Whereas 'B', 'C' and 'Cs' type tympanogram and absence of reflex were considered to be abnormal findings indicating pathological middle ear status. This criterion was considered based on the recommendation of FitzZaland and Zink (1984).

OAEs were also obtained for both the ears of all the children. DPOAEs were recorded using an f2: f1 ratio of 1.22: 1 and intensity level of 65 and 55 dB peak SPL (L1 and L2). The children were marked 'pass' and 'refer' based on the interpretation shown by the instrument. The instrument marked a child as 'pass' if 3 out of 5 frequencies were pass which met a minimum -5 dB SPL amplitude and a minimum 8 dB SNR, or a mini-

mum noise floor amplitude of -17 dB SPL (NIH, 2000). Testing was repeated in cases of 'refer' to confirm the findings.

Pure-tone audiometry was administered after instructing the children in Kannada or English, depending on their fluency in that language. Children were seated facing away from the audiometer to prevent them from getting any visual cues. AC thresholds in the octave frequencies 250 Hz to 8 kHz and BC thresholds in octave frequencies from 250 Hz to 4 kHz were measured using the modified Hughson and Westlake procedure. From the pure tone thresholds, PTA 1 (average of thresholds at 500 Hz, 1 kHz & 2 kHz) and PTA 2 (average of thresholds at 1 kHz, 2 kHz & 4 kHz) were calculated. Children having both AC and BC thresholds within 15 dB HL were considered to have normal hearing sensitivity. Correction, based on the biological calibration values were applied to arrive at the actual thresholds of the children.

Test-retest reliability

Test-retest reliability was determined for results obtained in all 3 phases. To check the test-retest reliability of the responses to the checklist, 4 of the teachers (40%) were again asked to answer it for 16 (10.38%) of the children who were randomly selected. The screening and diagnostic tests were also re-administered on these 16 children. Re-administration of all the tests was done after a gap of 3 days.

Analyses

The obtained data was tabulated and based on the test findings, the participants were divided into two groups depending on whether they passed or were referred depending on the screening checklist and / or screening test. The referred children consisted of 3 groups: Children who were referred based on the checklist alone; Children who were referred based on the screening test alone; and children who were referred based on both the screening checklist and the screening test.

The sensitivity and specificity of the two trial screening procedures (the checklist 'Signs and Symptoms of Hearing Loss' and the screening test, 'Ling's 6-sound screening test') as well as the positive and negative predictive values were determined. This was done by comparing the findings of the two trial screening procedures with standard procedures (Immittance screening & DPOAE, and pure tone thresholds). Additionally, the test-retest reliability of the screening procedures was also determined.

The data were subjected to statistical analysis using SPSS software (Version: 20). Kappa test of agreement was used to compare the findings of each of the trial screening procedures (checklist & Ling's 6-sound screening test) with the results of the standard screening and diagnostic battery. Comparison was also done between the combined results of the two screening procedures and the diagnostic tests. Further, the relationship between the checklist and the screening test was also determined using Kappa test. Cronbach's alpha (α) reliability co-efficient was determined to check the test-retest reliability of all the tests.

Results and Discussion

The results of the 154 children (308 ears) are discussed under four broad headings: A. Findings of the hearing checklist: B. Findings of the Ling 6-sound screening test; C. Findings of the combination of hearing checklist & Ling 6-sound screening test; D. Test retest reliability measures. For the screening checklist and the screening test the following are provided: the general outcome, the sensitivity and specificity, the agreement with the standard tests, and the positive and negative predictive values.

Findings of the Hearing Checklist

General outcome of the hearing checklist: Of the 154 school children evaluated, 45 were referred based on the findings of the screening checklist. The symptom that occurred most frequently was, 'Is the child always distracted and is engrossed in other activities while the class is being conducted? ' The other symptoms that were present fairly frequently were, 'Does the child ask for frequent repetition of the message being spoken?', 'Does the child have an evident mispronunciation?' and 'Does the child have ear pain?' The symptoms that were observed more frequently did not directly relate to the presence of hearing loss but were indirect indicators of the problem. This highlights that teachers relied more on overt symptoms that may be pointers to detect a hearing impairment, rather than a direct indicator of hearing impairment.

Further, cluster analysis was done to subgroup these questions. It was found that the question could not be clustered into different subgroups. This indicated that each question in the checklist was unique. Based on this it is recommended that all the questions be utilized while administering the checklist as they tapped different aspects related to hearing.

Sensitivity and Specificity of the Screening Checklist: To find out the effectiveness of the screening checklist, its sensitivity and specificity was calculated. This was done using the following formulae:

$$\text{Sensitivity} = \frac{\text{No. of participants having hearing loss}}{\text{Total number having hearing loss}} \times 100\%$$

$$\text{Specificity} = \frac{\text{No. of participants not having hearing loss}}{\text{Total number not having hearing loss}} \times 100\%$$

The findings of the checklist, when compared to the different standard tests, showed a sensitivity ranging from 33.6% to 49.3% and specificity ranging from 72.8% to 76.4%. The sensitivity and specificity varied depending on the standard test with which it was compared. With tymanometry as the standard test, the sensitivity and specificity were 49.3% and 76.3%. Similar sensitivity and specificity were obtained with the standard tests, acoustic reflex (42.2% & 76.3% respectively) and DPOAE (42.4% & 76.4% respectively). Comparatively lesser sensitivity values were found when diagnostic PTA 1 (38.5%) and PTA 2 (36.7) were the standard tests though specificity did not vary much (72.8% & 74.9%).

Further, the Kappa measure of agreement was done to check the agreement between the checklist and different standard tests. It was found that there was a poor agreement of less than 0.228 between the findings of the screening checklist and that of the standard screening tests. However, this agreement was statistically significant ($p < 0.05$) for PTA 2, tympanometry, acoustic reflex and DPOAE.

Thus, from the findings of the sensitivity, specificity and Kappa measure of agreement, it can be inferred that the checklist was not effective in detecting the presence of hearing impairment. Similar findings have been reported in literature by Curry (1950), who found that only 7.4% out of all children who might have had a hearing loss were referred by school teachers.

Predictive values for the screening checklist: The positive predictive value (PPV) and negative predictive value (NPV) of the checklist were calculated to determine the over referral and under referral rates. PPV provided information regarding the ratio of the number of children detected correctly by the checklist as having a hearing problem to the total number of children who were positive on the checklist. Similarly, negative predictive value (NPV) calculated the ratio of the number of children who were detected correctly by the checklist to not have a hearing problem to the total number of those who were negative on the checklist. The values were calculated using the following formulae:

$$\text{PPV} = \frac{\text{No. identified correctly to have a problem}}{\text{Total number positive on the checklist}} \times 100\%$$

$$\text{NPV} = \frac{\text{No. identified correctly to not have a problem}}{\text{Total number negative on the checklist}} \times 100\%$$

The use of only the screening checklist resulted in unacceptably high over-referral (56.7% to 71.1%) and under-referral (68.3% to 84.4%) rates. The over-referral and under-referral rates varied depending of the standard test. Almost similar over-referral rates were found with PTA 2 (56%), acoustic reflex (56.7%), DPOAE (61.1%) and tympanometry (63.3%) as standard tests. A slightly higher over-referral rate was found when PTA 1 was considered as standard test. Almost similar under-referral rates were found with PTA 1 (78.4%), tympanometry (84.4%), acoustic reflex (75.7%) and DPOAE (78%) as standard tests. However, slightly lower under-referral rate (68.3%) was found with PTA 2. These results are in agreement with the findings of Olusanya (2001), who found that the sensitivity and specificity for a hearing screening questionnaire were 10 % and 94 %. In the same study a positive predictive value of 21.7% was found for the questionnaire. However, Lo, Tong, Wong and Hasselt (2006) in an effort to determining the accuracy of parental suspicion to detect hearing problem in children, found a sensitivity of 19.7% and specificity of 96.9 %. Further, they also got a positive predictive value of 82% and negative predictive value of 62.1%. The sensitivity reported by them is comparable with the findings of the present study. However, the positive (28.9% to 44%) and negative (15% to 31.7%) predictive values were comparatively lower in the present study. Their higher values were probably obtained because the responses were obtained from parents who were more sensitive to the presence of a hearing problem in their wards than school teachers. In the present study, the checklist was answered by the teachers who probably did not have the same level of sensitivity to the presence of a hearing problem as parents. This discrepancy can be attributed to the fact that parents spent more one-on-one time with the children and hence could detect the presence of a hearing problem. Another reason could have been that the parents had to make judgments about only a limited number of children whereas teachers had to make judgments about a much larger number of children.

The findings of the present study and that published in literature highlight that using teachers to answer checklists to identify hearing impairment is not a useful procedure. Based on these findings, it is not recommended to use solely checklists answered by teachers to screen for the presence of hearing impairment in school-going children.

Findings of the Ling 6-sound Screening Test

General Outcome of the Ling 6-sound Screening Test: From the data of 154 children (308 ears) that were analyzed, 58 children (104 ears) were referred for further testing based on the scores obtained on the screening test (score < 6). These 58 children did not correctly respond to one or more speech sounds of the test. Out of the 58 children, 12 of them did not pass the screening test in only one of their ears and 46 of them did not pass the test in both their ears.

The data were also analyzed for each speech sound separately. This was done to see if the referral differed depending on specific speech sounds. Table 1 summarizes the number of ears that were referred based on the responses for the different speech sounds of the Ling's test.

Table 1: Number of ears referred based on the responses for each of the speech sounds of the Ling's 6-sound test

Speech Sound	Number of ears referred (Total: 308)
/a/	50 (16.23 %)
/i/	66 (21.42 %)
/u/	60 (19.48 %)
/s/	94 (30.52 %)
/sh/	81 (26.29 %)
/m/	86 (27.92 %)

As evident from Table 1, the maximum number of ears was referred for the sound /s/ followed by /m/ and /sh/. McNemar test for related samples was done to check if there was a statistically significant difference in the referral for the six different speech sounds. Statistically significant differences at 0.001 level were found between all combinations of the sounds except for the combinations of /i/ - /u/ and /s/ - /m/. These combinations were not statistically significant even at the 0.05 level.

The results regarding the referral rate based on the Ling's sound test indicated that the perceptual difficulties of these speech sounds were distinctly different. This probably occurred due to the different acoustic characteristics of the speech sounds which tapped perceptual difficulties across different frequencies. The speech sounds /i/ - /u/ and /s/ - /m/ yielded similar results probably because these combinations were similarly affected though they had contrastive frequency responses. An examination of the raw data indicated that a large number of ears had problems in perceiving both the combination of speech sounds. Fifty-four of the 104 ears had difficulty in perceiving both /i/ and /u/ while 80 of the 104 ears had problem perceiving both /s/ and /m/. This highlights that though these speech sounds that had contrastive acoustic patterns they affected the children in a similar manner.

It was also found that /s/ ($p < 0.001$) and /sh/ ($p < 0.001$) were statistically significantly different from all or most of the other Ling's sounds, except the former which did not differ from /m/. It was also seen that these sounds lead to higher referral rates when compared to other speech sounds. This indicates that these two speech sounds were more sensitive to the auditory perceptual problems of children.

The possibility that the perception of the sound could have been due to the presence of low frequency ambient noise in the environment was ruled out. Had the ambient noise affected the test results, it should have affected all the children in a similar manner. Further, the biological calibration that was carried out regularly ensured that the ambient noise did not affect the results. Thus, it can be inferred that the test tapped the auditory perceptual difficulties of the children and was not affected by extraneous factors such as ambient noise.

Sensitivity and Specificity of the Ling's 6-sound Screening Test: In order to find out the effectiveness of the Ling's 6-sound screening test in identifying hearing loss, the findings of it were compared with that of the standard tests that included pure-tone tests and standard screening tests (tympanometry, acoustic reflexes & DPOAE). The sensitivity and specificity were determined using a similar procedure as was done for the screening checklist. Sensitivity of the Ling's 6-sound (Table 2) test was found to be highest (82 %) when it was compared with the gold standard test, DPOAE followed by tympanometry (77.6%). Almost similar sensitivity was found when it was compared to PTA 1 (76.7%%), PTA 2 (68.9%) and acoustic reflex test (72.5%). It was the least (62.9%) for the combination of PTA and tympanometry.

The specificity for the Ling's 6-sound test (Table 2) did not vary much when it was compared with different standard procedures. The highest specificity was found when compared with the acoustic reflex test (90.3 %) followed by that of a combination of PTA and DPOAE (89.1 %). Comparable specificity was seen when other tests were used as the standard (PTA 2, tympanometry, combination of PTA and tympanometry). The specificity was the least when compared with PTA 1. Kappa coefficient revealed that there was a good agreement that ranged from 0.47 to 0.64 between the results of Ling's screening test and the various standard tests. This agreement, in all the instances, was statistically significant ($p < 0.05$).

Predictive Values for the screening test: The positive and the negative predictive values for the Ling's 6-sound screening test were high. This resulted in a low over referral and under referral rate for the screening test with respect to different standard tests. The Ling's 6-sound screening test had a relatively lower over referral (18.3% to 50%) and very low under referral (7.4% to 24%) rates than the hearing screening checklist. It can therefore be concluded that this screening test is a better predictor of hearing loss than the screening checklist that was used in the present study.

The agreement of each of the Ling's 6 speech sounds with the standard tests was also determined using Kappa test of agreement (Figure 1). Among the 6 sounds, /s/ (0.48 to 0.63) followed by /sh/ (0.46 to 0.61) had the highest agreement with acoustic reflex test and DPOAE. However, these levels of agreements were generally lower than the values got when the scores of all the 6 sounds (0.49 to 0.64) were combined and used. This probably happened since the 6 different speech sounds covered a range of frequencies that were able to detect hearing losses that occurred in different frequency regions. In contrast, isolated speech sounds probably

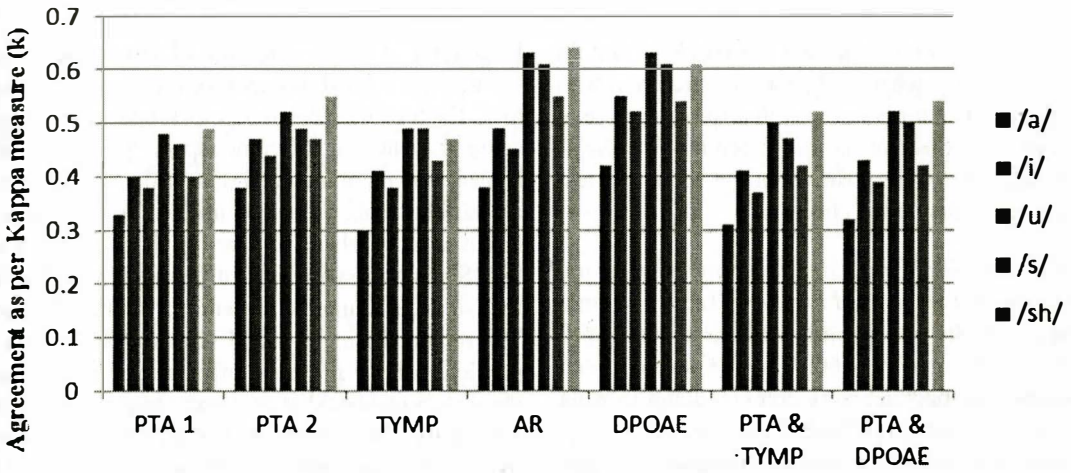

Figure 1: Agreement for each sound with different diagnostic and standard screening test.

Table 2: Sensitivity and specificity of the checklist and the screening test combined and in isolation

		Diagnostic Tests		Standard screening tests		
		PTA 1	PTA 2	TYMP	AR	DPOAE
Checklist & screening test combined	Sensitivity	69.2 %	76.1 %	85 %	85.9 %	86.7 %
	Specificity	66 %	67.8 %	63 %	68.5 %	66.7 %
Checklist	Sensitivity	38.5 %	36.7 %	49.3 %	42.4 %	42.2 %
	Specificity	72.8 %	74.9 %	76.3 %	76.4 %	75.6 %
Ling's screening test	Sensitivity	76.7 %	68.9 %	77.6 %	72.5 %	82 %
	Specificity	79.6 %	85.4 %	78.4 %	90.3 %	84 %

Note: PTA 1 = pure tone average of 500 Hz, 1 kHz and 2 kHz; PTA 2 = pure tone average of 1 kHz, 2 kHz and 4 kHz; TYMP = tympanometry; AR = acoustic reflexes

tapped only specific frequencies and miss identifying hearing problems in other frequencies. Hence, the use of isolated speech sounds to speed up the screening process is not recommended. Using all the 6 sounds is suggested to improve the sensitivity, specificity as well as reduce the over referral and under referral.

The findings of the Ling's 6-sound screening test indicate that a fairly large number of children were suspected to have a hearing loss (Table 1). These findings are supported by previous studies done on prevalence of hearing loss among school children. Mishra, Bhatia and Bhatia (1961) investigated 1390 school going children in Lucknow city of North India. They found that the prevalence of hearing loss was 34%, with the majority of children having conductive hearing loss. Kapur (1965) found the prevalence of hearing loss among children aged between 5 to 15 years to be 18.6%. It was opined that this high prevalence was because of the presence of middle ear pathology. Recently, Sarafraz and Ahmadi (2009) found that out of a total of 785 school going children studying in first and second grade, 306 (39%) had hearing loss. This finding was based on tympanometry test results which substantiated the high prevalence of middle ear disorders in school age children.

Thus, it is possible that the high referral rate seen in the Ling's 6-sound screening test in the present study was on account of the presence of a middle ear problem which is commonly seen in school children. The sensitivity and specificity of the Ling's 6-sound screening test confirms that the test is a valid and useful procedure to detect hearing loss in school going children.

Findings of the Combination of Hearing Checklist & Ling 6-sound Screening Test

General outcome of the screening checklist & screening test when used together: In order to find out the effectiveness of the combined findings of the screening checklist and the screening test, the joint findings were compared with the standard test findings. The sensitivity and specificity were calculated and tabulated from the decision matrix for the combined screening protocol. The decision of 'pass' was made only if the children 'passed' both the checklist and the screening test. Likewise, the decision of 'refer' was made if the children were 'referred' based on any one or both the

screening procedures.

Of the 308 ears, 160 passed both the checklist and the Ling's 6-sound test, whereas 46 ears were referred from both of them. The number of ears that were negative on the checklist but positive on the screening test was 44 while 58 ears that were positive on the screening test, had negative results on the checklist.

Sensitivity and specificity of the screening checklist and the screening test when used together: Table 2 summarizes the sensitivity and specificity of the screening procedures when the outcome of the Ling's 6-sound screening test and the checklist were combined and in isolation. It can be observed in Table 2 that the sensitivity of the combined screening procedures (checklist & Ling's 6-sound screening test) was marginally better or comparable to the Ling's 6-sound test in isolation. However, the specificity dropped when the combination was used. Thus, it is recommended that the Ling's 6-sound screening test could be used in isolation in order to have a balanced sensitivity and specificity. Further, the checklist, when used in isolation, had a very low sensitivity and hence is not recommended to be used separately.

The findings of the present study is in consonance with that of by Curry (1950), who opined that the task of identifying hearing problem should not be carried out on the basis of teachers' referrals. From the present study, it is recommended that the Ling's 6 sound screening test be used in isolation instead of along with a checklist for school screening programs. This screening test can be carried out without expensive audiological equipment, provided adequate measures are taken to calibrate the output signal from the computer that is required to be used.

Test-retest reliability measures

Reliability of the screening checklist was determined by administering the alpha reliability co-efficient test. Since there was no change in the responses of the teachers, the alpha reliability co-efficient was 1. This high reliability probably occurred since the teachers answered the checklist for the second time within a span of just three days. However, these results confirm that the teachers were able to provide consistent and reliable responses.

The test-retest reliability of the Ling's 6-sound screening test that was checked on 16 children was found to be high. This was established since the alpha reliability co-efficient was greater than 0.6 [? = 0.73, ($p < 0.05$)].

The testretest Reliability of the standard audiological diagnostic tests (pure-tone audiometry, tympanometry, acoustic reflexes and DPOAE) indicated that there was no change in the responses after 3 days. This confirmed the reliability of the responses obtained from the participants.

Conclusions

In general, a single symptom of the screening checklist was not a good indicator of the presence of hearing loss. Each of the questions was found to be unique because they tapped different aspects related to hearing. Hence, it is recommended that, if the checklist is used, all the questions should be utilized as they tapped different aspects related to hearing. The screening checklist 'Signs and symptoms of hearing loss' was not effective in detecting the presence of hearing impairment. The recorded Ling 6-sound screening test was a better predictor of the presence of hearing loss compared to the screening checklist as it had a higher sensitivity and specificity. The screening test also had relatively low over referral and under referral rates as compared to that of the checklist. The combination of the checklist and the screening test did not give rise to significant better results. The sensitivity of the combined protocol ranged from 69.2 % to 86.7 % and specificity ranged from 63 % to 68.5 %, which is almost similar to that of when the Ling's 6-sound screening test alone. Since the inclusion of the checklist did not improve the effectiveness of the screening program, use of the Ling's 6 sound screening test in isolation is recommended. The test is also recommended since it does not require the use of sophisticated instrumentation.

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