Equivalence of The Matrix Sentence Test in Indian-English in The Presence of Noise

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Abstract

The objective of the study was to evaluate the equivalence of sentence lists of the 'Matrix Sentence Test in Indian-English' developed by Bhattarai and Yathiraj (2015) in the presence of noise as well as determine the difference in performance between children and young adults.A purposive sampling technique was used to select the participants. Initially, a pilot investigation was done to determine the appropriate signal-to-noise ratio to establish SNR-50; a pilot study was conducted on 5 normal hearing children and 5 normal hearing young adults. The sentences were presented at a constant level, equivalent to normal conversation (45 dB HL), and an 8-talker babble was varied to establish SNR-50. SNR-50 was obtained at 0 dB SNR for the children and -5 dB SNR for the young adults. Using these values, SNR-50 was evaluated on 60 participants. These participants were divided into four age groups with 10 individuals each in the younger three age groups [7 year olds (7.1 to 8 years), 8 year olds (8.1 to 9 years), 9 year olds (9.1 to 10 years)] and 30 young adults aged 18 to 25 years. No significant effect of age was found on the sentence identification scores in the presence of speech babble for 48 lists of the 50 lists of the 'Matrix Sentence Test in Indian-English'. The lists, 23 and 33 that were found to vary across ages were eliminated for further analyses. Among the 48 lists, it was found that 37 lists were equivalent and 11 lists were unequal in the presence of noise. The 48 sentence lists that had no age effect can be used to test sentence identification scores for both children and adults in the presence of noise. Among these, 37 lists can be used interchangeably. It is suggested to regroup the 11 unequal lists after eliminating sentences with specific words that yielded poor scores.

Key words: *Matrix test, sentences, Indian-English*

Introduction

Speech perception tests are regarded as having more clinical utility than pure-tone audiometry for identifying individuals with poor auditory analytical potential as they also assess higher-level linguistic activities (Wang, Mannell, Newall, Zhang, & Han, 2007). In addition to the assessment of difficulty in communication, speech perception tests have been found to be useful in detecting difficulties in different types and degrees of hearing loss, hearing aid selection, identifying functional hearing loss and site of lesion (Kutz, Mullin, & Campbell, 2010).

The speech stimuli that have been commonly used in speech audiometry include phonemes, nonsense syllables, monosyllables, spondees, phrases, sentences and paragraphs (Dias et al., 2015; Tyler, 1994). Nonsense syllables have been reported to be the most difficult to recognize (McArdle & Hnath-Chisolm, 2009). They have been noted to have extremely low semantic content and yield very little information about handicap and disability experienced by an individual in daily life (Gatehouse & Robinson, 1997). It is also reported that monosyllables lacked lexical, syntactic, semantic and dynamic cues (Cox, Alexander, & Gilmore, 1987). Likewise, spondees were found to not depict natural language communication as they are evaluated in isolated utterances or carrier phrases. This was found to result in poor representation of supra-segmentals, pauses, spectral weighting and other aspects of conversational speech (Nilsson, Soli, & Sullivan, 1994).

As the rapid nature of speech is noted to be missed with the use of phonemes and words for assessing speech identification, sentences and paragraphs have been considered as better choices of stimuli (Tyler, 1994). Additionally, sentences have been found to have better intelligibility function compared to words. Earlier researchers also noted that assessment of co-articulation and temporal aspects of speech are possible with the use of sentences (Miller, Heise, & Lichten, 1951). Sentences were observed to provide information regarding the time domain of everyday speech and approximate contextual characteristics of conversational speech (Jerger, Speaks, & Trammel, 1968).

In children, speech recognition measures have been reported to provide relevant information about the auditory system, making it possible to predict the development of different skills such as language, reading and cognitive abilities. Furthermore, as recommended in adults, sentence intelligibility tests are recommended for children instead of word tests as the latter provide limited information about speech perception skills (Bell & Wilson, 2001). According to Mendel (2008), sentence tests should be a component of every battery of audiologic tests for children.

In literature, tests have been constructed either using every day sentences [e.g. (Kollmeier, 1997; Nilsson et al., 1994; Plomp & Mimpen, 1979)] or with a ?xed syntactical structure such as the 'Matrix sentence tests' (Hagerman, 1982; Hochmuth et al., 2012; Ozimek, Warzybok, & Kutzner, 2010; Wagener, Brand, & Kollmeier, 1999; Wagener, Josvassen, & Ardenkjar,

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2003). The latter format has been reported to have numerous advantages over the former. The major advantage is the low redundancy and semantic unpredictability, thus preventing contextual information from influencing a listener's response (Hochmuth et al., 2012). The other advantage of the Matrix sentence test, according to Hagerman (1982), is the difficulty in memorizing the sentences due to their lower redundancy, thereby allowing testing the same individual multiple times. The test was reported to have syntactically fixed sentences that could not be predicted semantically (Dreschler et al., 2006; Hagerman, 1982; Puglisi et al., 2014).

It has been suggested that sentence identification should tested in the presence of noise having a similar long term average spectrum as that of the speech signal. Speech recognition in noise has been found to provide insight into the speech perception difficulties faced by an individual and help determine the potential benefits obtained from amplification (Levy, Freed, Nilsson, Moore, & Puria, 2015; Nittrouer, Tarr, Wucinich, Moberly, & Lowenstein, 2015; Picou, Marcrum, & Ricketts, 2015; Turner & Henry, 2002; Wilson & McArdle, 2005). It is reported that the use of masking noise also improves the sensitivity of a speech test. McArdle, Wilson, and Burks (2005) provided evince that presenting speech at various SNRs in multi-talker babble produced a steeper psychometric function slope than when speech materials were presented in quiet. According to Hochmuth et al., (2012), compared to testing in a quiet situation, the use of masking noise was found to distinguish the group with hearing impairment from those with normal hearing, with a separation of approximately 8 dB. This was attributed to difficulty in understanding speech in noisy environments by individuals with hearing impairment.

Additionally, speech-in-noise tests are noted to also identify pathologies associated with impaired temporal processing. Poor speech discrimination in quiet, despite normal pure-tone audiogram, is reported to support the diagnosis of auditory neuropathy (Starr, Picton, Sininger, Hood, & Berlin, 1996). This information has also considered being helpful in counseling patients regarding their expectations about benefits from hearing devices when listening in background noise (Wilson & McArdle, 2005). Further, estimating speech thresholds in the presence of noise has been found to provide an indication regarding the choice of rehabilitation (Katz, 2009). An additional advantage of using sentence tests in noise is that they represent a more realistic conversational situation than speech in quiet or isolated words. It is reported that difficulty in understanding speech in noisy environments also corresponds to the main complaint of individuals with hearing impairment.

The use of noise when testing with the Matrix sentence test has been recommended in the Swedish Matrix Sentence Test (Hagerman, 1982), which was the first matrix sentence test, and the French Matrix Sentence Test (Jansen et al., 2012). Similar tests have been developed in several other languages with the recommendation that they be presented in the presence of noise. These tests include the Polish Matrix Test (Ozimek et al., 2010); German Matrix Test (Wagener et al., 1999); Polish Pediatric Matrix Sentence Test (Ozimek, Kutzner, & Libiszewski, 2012); Spanish Matrix Test (Hochmuth et al., 2012); Turkish Matrix Test (Zokoll, Hochmuth, Fidan, Wagener, & Kollmeier, 2012); Italian Matrix Test (Puglisi et al., 2014); Finnish Matrix Test (Dietz et al., 2014); American-English Matrix Test (Zokoll, Wagener, et al., 2012); New Zealand-English Matrix Test (O'Beirne, 2015); Dutch Matrix Test (Houben et al., 2014) and Russian Matrix Test (Warzybok & Zokoll, 2015). The Matrix Sentence Test in Indian-English (Bhattarai & Yathiraj, 2015) was developed for children and validated in quiet. The performance of participants in the presence of noise was not evaluated.

It is known that perception of speech in quiet is very different from perception in the presence of noise (Hochmuth et al., 2012; Jain, Kodanath, Vimal, & Suresh, 2014; Nilsson et al., 1994; Ozimek et al., 2010; Wong, Soli, Liu, Han, & Huang, 2007). Nilsson et al, (1994) reported that the equivalence of material in quiet is not similar to that in the presence of noise. Further, the Matrix Sentence Tests are found to be of greater clinical utility in the presence of noise than in a quiet situation, as natural communication usually takes place in a noisy environment (Hochmuth et al., 2012). Hence, there is a need to appraise the equivalence of the sentence lists of the Matrix Sentence Test in Indian-English (Bhattarai & Yathiraj, 2015) in noise as its equivalence has only been determined in quiet. There is also a need to check if children and young adults perform in a similar manner in the presence of noise so that the same test can be utilized in both age groups.

Aim

The aim of the study was to evaluate the equivalence of sentence lists of the 'Matrix Sentence Test in Indian-English' developed by Bhattarai and Yathiraj (2015) in the presence of noise as well as determine the difference in performance in children and young adults.

Methods

The study aimed to determine the equality of the Matrix Sentence Test in Indian-English (Bhattarai & Yathiraj, 2015) in the presence of noise. The study was conducted in two stages. The first stage encompassed a pilot study carried out to determine SNR-50. In the second stage children and adults were tested with the Matrix Sentence Test in Indian-English in the presence of noise, using the noise level established in the pilot study.

Participants

The participants were selected using a purposive sampling technique. For the pilot study conducted, 5 children aged 7 years and 5 young adults aged 18 years were evaluated. In the second stage, 30 school-going children in the age range of 7 to 10 years and 30 young adults aged 18 to 25 years were assessed. The 30 children were divided into three age groups [7 year olds (7 to 8 years); 8 year olds (8.1 to 9 years), & 9 year olds (9.1 to 10 years)] with each group having 10 children. Prior to testing the participants, informed consent was obtained from their caregivers as detailed in the ethical guidelines of AIISH (Ethical Guidelines for Bio-behavioral Research involving human subjects, 2009). All the children and young adults had no complaint of hearing loss, indicated by them having pure-tone average thresholds of 15 dB HL in the frequencies between 250 Hz and 8 kHz for air conduction and 250 Hz and 4 kHz for bone conduction; no history or complaint of middle ear problems, confirmed by the presence of 'A' type tympanograms with acoustic stapedial reflexes present in both ears; normal speech and language development; and no history of psychological or neurological problems. Additionally, the participants were selected only if the children had an exposure to Indian-English for at least 3 years. The young adults were fluent speakers of the language with a minimum of 5 years of exposure to it in an educational institution.

Material

The Matrix Sentence Test in Indian-English, developed by Bhattarai and Yathiraj (2015) was used. The test contains 50 lists that are reported to be equivalent in a quiet situation and 7 practice items. Each list has 10 sentences and each sentence has a fixed semantic structure that consists of five word categories ('name', 'verb', 'number', 'adjective' & an 'object'). The sentences were reported to be initially derived from 50 different words, with 10 alternatives for each word category, as was recommended by Hagerman (1982).

Eight-talker speech babble developed by Yathiraj, Vanaja and Muthuselvi (2009) was used as noise. The babble contained the speech of 4 males and 4 females who were fluent English speakers, with a neutral Indian accent. The babble was chunked into individual segments having similar amplitude across the segment.. It was ensured that the amplitude of the noise segment was similar to that of the sentences. Each noise segment starts 500 ms before the sentence and ends 500 ms after the sentence.

Equipment

A calibrated dual channel audiometer, Inventis Piano, was used to measure pure-tone thresholds and for the presentation of the speech stimuli. While the air conduction tests were conducted using a TDH-39 headphone, a radio ear B71 bone vibrator was used for estimating bone conduction thresholds. A calibrated middle ear analyzer (GSI TympStar) was used to rule out the presence of middle ear problems. Otoacoustic emissions were estimated in all participants to rule out outer hair cell abnormalities using Institute of Laryngology and Otology, version 6 (ILOv6). The CD versions of the sentences as well as the eight-talker speech babble were played through a Hewlett-Packett laptop (32 bit core i5 processor) loaded with Adobe Audition (v3.0).

Test Environment

Evaluations were carried out in a well illuminated sound treated room. The noise levels within the room were within permissible limits (American National Standards Institute, 2008).

Procedure

Stage 1: Pilot Experiment

In order to estimate the signal-to-noise ratio that results in SNR-50, a pilot study was conducted on 5 school-going normal hearing children aged 7 years and 5 young adults aged 18 years who meet the participation selection criteria. This enabled determining the signal-to-noise ratio at which the participants were able to get at least 50% scores on the Matrix Sentence test in Indian-English. The scores on the Matrix Sentence test in Indian-English (Bhattarai & Yathiraj, 2015) were determined in the presence of ipsilateral eight-talker speech babble (Yathiraj et al., 2009). Ten lists from the Indian-English Matrix Sentence Test that were randomly selected from the 50 available lists were utilized for the pilot investigation.

The speech stimuli were presented at a constant level equivalent to normal conversation (45 dB HL) and the noise was varied in 5 dB steps from -10 dB SNR to +10 dB SNR, in order to establish SNR-50 (the SNR that results in 50% score). Two sentence lists were used for each of the 5 SNRs. The order of presentation of the lists was randomized for all the participants. It was noted that the children obtained SNR-50 at a signal-to-noise ratio of 0 dB while the young adults obtained the same at a signal to noise ratio of -5 dB.

Stage 2: Establishment of sentence identification in the presence of noise

Procedure for participant selection:

Prior to running of the Matrix Sentence test in Indian-English, all the participants were evaluated to establish whether they met the participant selection criteria. They underwent pure-tone audiometry, tympanometry, otoacoustic emissions and otoscopic examination to rule out any hearing loss. The participants were included in the study if they had pure-tone thresholds less than 15 dB HL in both ears at the frequencies 0.5, 1.0, 2.0, 4.0, and 8.0 kHz; A-type tympanograms; acoustic reflexes present in both ears; and presence of otoacoustic emissions with at least 6 dB SNR, at three consequent frequencies. Absence of any speech, language disorder or any other associated problem was ensured through a case history.

Procedure for administration of sentence-in-noise test:

The sentence test was administered along with the eight-talker speech babble on 30 typically developing children aged seven to ten years as well as 30 young adults who meet the participant selection criteria. The sentences and the eight-talker speech babble were presented with a HP laptop computer loaded with Adobe Audition software (version 3). Both the sentences and the noise were routed to the same ear through TDH-39 headphones via an audiometer. The stimulus was presented at 40 dB SL that represents normal conversational level. The noise was presented at the level selected in the pilot study, that is, 0 dB SNR for the children and -5 dB SNR for the young adults.

All the participants were instructed to repeat the sentences heard through the headphones as accurately as possible and to ignore the concurrent eight-talker speech babble. Prior to the actual testing, the participants were familiarized using the practice items. Each participant heard all 50 lists of the Matrix Sentence Test in Indian-English in different random orders to prevent test order contaminating the results. Half the participants from each age group were tested in the left ear and the other half was tested in the right ear to minimize an ear effect. Adequate breaks were provided in case a participant showed signs of fatigue or restlessness. Testing was carried out in multiple sessions depending upon the participant's level of interest and fatigue. The older children (9.1 to 10 years) required not more than 2 sessions whereas the younger children (7.1 to 9 years) required 2 to 3 sessions. The young adults, however, were able to finish the task in a single session with a break of 10 minutes after every 15 lists.

Scoring

Word scores were calculated for each individual. The scores were computed by awarding each word that is correctly identified a score of '1' and a wrong response a score of '0'. The maximum possible score for each sentence list was 50. The scoring process was simplified using Microsoft Excel 2007 where scores were keyed in manually for each word and the sum function (SUM fx) facility of the spreadsheet was used to calculate the total score per list.

Analyses

The scores obtained were analysed using SPSS software (version 17). A Shapiro-Wilk test of normality was used to check normal distribution of the sample taken. As it was found that the scores on most of the lists were not normally distributed, non-parametric statistics was done. Besides descriptive analyses inferential statistics was carried out. A Kruskal-Wallis test was done to check for any age difference. A Friedman's test was run to determine a significance of difference between the 50 sentence lists. Further, a Wilcoxon signed ranks test was administered to check pair-wise difference between the lists.

Results

The scores obtained for all the 50 sentence lists were subject to analyses to determine whether there was an effect of age on speech identification scores in noise and also to check inter-list equivalency. Prior to carrying out the non-parametric statistics, a box plot was drawn to check for the presence of any outliers.. Four participants were found to be outliers and therefore were excluded (one each from the second and third age group, and two from the young adults), thereby reducing the total participants in the sample from 60 to 56. Details of age effect and inter-list equivalency are provided below.

a) Effect of age on speech identification scores

To determine if there existed a significant difference between the performance of the four age groups, Kruskal-Wallis test was administered on each of the 50 lists. The test revealed a significant difference across the four age groups for two of the lists, List 23 [(3) = 8.878, $p < 0.05$] and List 33 [(3) = 9.744, $p < 0.05$). However, no significant difference between age groups was observed for the remaining 48 sentence lists ($p > 0.05$).

Subsequently, a Mann-Whitney U test was administered to check which pairs of the four age groups were significantly different for List 23 and List 33. The results revealed no significant difference between the 7 and 8 year olds for both the lists (List 23: $z = -1.356$, $p > 0.05$; List 33: $z = -1.942$, $p > 0.05$). Similar findings were observed between the 8 and 9 year olds (List 23: $z = -1.648$, $p > 0.05$; List 33: $z = -0.137$, $p > 0.05$); and between the 8 year olds and the young adults (List 23: $z = -0.303$, $p > 0.05$; List 33: $z = -0.181$, $p > 0.05$). However, between the 7 year olds and the 9 year old a significant difference was found for list 33 ($z = -2.602$, $p < 0.05$) but not for list 23 ($z = -0.288$, $p > 0.05$). On comparing the 9 year olds and the young adults, the reverse finding was observed. A significant difference was seen for list 23 ($z = -2.476$, $p < 0.05$) and no significant difference for list 33 ($z = -0.402$, $p > 0.05$). A significant difference was obtained for both the lists between the youngest and the oldest age groups (List 23: $z = -2.151$, $p < 0.05$; List 33: $z = -2.993$, $p < 0.05$).

Due to the significant difference between the scores of the four age groups on Lists 23 and 33, they were eliminated from further analyses. The scores obtained by the four age groups on each of the remaining 48 lists were combined and the data were subjected to further analyses.

b) Comparison of scores across lists

With age groups combined, it was found from the results of the Shapiro Wilk test that many of the lists continued to not be normally distributed. Hence, non-parametric tests continued to be used. Friedman's test was run on 48 sentence lists, excluding lists 23 and 33 that were found to vary across ages. Prior to carrying out the Friedman's test the lists were arranged based on their mean scores in an ascending order. When the data of all 48 lists were included, it was found that there existed a significant overall effect of the list equivalency [(47) = 161.09, $p < 0.05$]. Hence, the Friedman's test was administered repeatedly after gradually eliminated the lists with extreme mean scores, one by one. Initially, the list with the least score was removed and the Friedman's test was run on the remaining 47 lists. Following this the list with the maximum score was removed and the test was run on the remaining 46 lists. This gradual elimination continued till no significant difference was found between lists on the Friedman's test. It was finally found that after eliminating 3 lists having the least mean scores and 8 lists having the maximum mean scores, no significant overall effect of the list equivalency was seen on the Friedman's test [(36) = 50.288, $p > 0.05$]. More lists from the extreme having higher scores were eliminated as several of the lists had similar scores. The lists that were found to be equivalent and those found to be not equivalent in the presence of speech babble are listed in Table 1.

The numbering of the lists are the same as that given for the Matrix Sentence Test in Indian-English by Bhattarai and Yathiraj (2015).

A Wilcoxon signed ranks test was administered on the 11 lists (represented by # in Table 1) that were significantly different from the 37 other lists that were equivalent (represented by in Table 1). This pair-wise test was done to check if they are significantly different from the other lists. The lists with which these 11 lists were found to be equivalent with are provided in Table 2.

From the findings of the study it can be seen that 48 of the 50 sentence lists of the Matrix Sentence Test in Indian English (Bhattarai & Yathiraj, 2015), tested in the presence of noise were not significantly different across the age groups. Hence, these can be utilized to test both children and adults. Only lists 23 and 33 had significant differences across the age groups. Further, among these 48 sentence lists that had no age effect, 37 were found to be equivalent in the presence of noise. Thus, they can be used interchangeably in determining speech identification scores in presence of noise.

Table 1. : Mean Scores for 48 sentence lists of the Matrix Sentence Test in Indian English in the presence of speech babble, with age groups combined (information for lists 23 & 33 not provided since they varied across age groups).

Lists No.	Mean	Median	SD	Lists No.	Mean	Median	SD
List 1$^{\approx}$	25.45	26	3.31	List 26$^{\approx}$	24.63	25	2.7
List 2$^{\#}$	23.77	24	2.54	List 27$^{\approx}$	24.27	24	1.93
List 3$^{\approx}$	24.45	24	2.01	List 28$^{\approx}$	24.82	24	2.24
List 4$^{\approx}$	24.7	25	2.57	List 29$^{\approx}$	24.46	24	2.34
List 5$^{\approx}$	24.27	24	2.53	List 30$^{\approx}$	24.38	24	2.04
List 6$^{\approx}$	24.54	24	2.2	List 31$^{\approx}$	24.52	25	2.06
List 7$^{\approx}$	24.73	24	2.81	List 32$^{\#}$	25.63	25	2.31
List 8$^{\approx}$	25.16	25.5	2.67	List 34$^{\#}$	23.84	24	2.34
List 9$^{\approx}$	24.48	24.5	2.46	List 35$^{\approx}$	25.64	25	2.89
List 10$^{\#}$	25.86	25	2.6	List 36$^{\#}$	26	26	2.25
List 11$^{\approx}$	25.23	25	2.78	List 37$^{\#}$	25.61	26	2.48
List 12$^{\approx}$	24.38	24	2.68	List 38$^{\approx}$	25.14	25	2.49
List 13$^{\approx}$	25.21	24	2.33	List 39$^{\approx}$	25.04	24.5	2.81
List 14$^{\approx}$	25.71	25	3.09	List 40$^{\#}$	26	25	2.53
List 15$^{\approx}$	25.38	26	2.29	List 41$^{\approx}$	24.8	24	2.53
List 16$^{\approx}$	24.98	25	2.09	List 42$^{\approx}$	24.75	24	2.57
List 17$^{\#}$	25.57	25	2.09	List 43$^{\approx}$	24.46	24	2.22
List 18$^{\approx}$	24.8	25	2.51	List 44$^{\approx}$	25.16	25	2.18
List 19$^{\approx}$	24.86	25	2.37	List 45$^{\#}$	24.18	24	2.37
List 20$^{\approx}$	25.04	25	2.03	List 46$^{\#}$	25.79	25	2.57
List 21$^{\approx}$	24.36	24.5	2.35	List 47$^{\approx}$	24.39	24	2.16
List 22$^{\approx}$	25.27	25	2.35	List 48$^{\approx}$	25.2	25	2.6
List 24$^{\approx}$	24.55	24.5	2.21	List 49$^{\#}$	25.8	25	2.58
List 25$^{\approx}$	25.52	25	3.25	List 50$^{\approx}$	24.75	24	2.55

Note : Sentence lists that are found to be equivalent to each other in the presence of noise.

#Sentence lists that are found to be significantly different from the rest of the lists in the presence of noise.

Maximum score for each list = 50

Table 2 : Sentence Lists of the Matrix Sentence Test in Indian-English in the presence of noise that are equivalent (represented by) and non-equivalent with reference to the 11 non-equivalent lists

List No	2	10	17	32	34	36	37	40	45	46	49	List No	2	10	17	32	34	36	37	40	45	46	49
1		☑	☑	☑		☑	☑	☑		☑	☑	26	☑						☑		☑		
2	☑				☑				☑			27	☑				☑				☑		
3	☑				☑				☑			28									☑		
4				☑			☑		☑			29	☑				☑				☑		
5	☑				☑				☑			30	☑				☑				☑		
6					☑				☑			31	☑								☑		
7			☑	☑			☑		☑			32		☑	☑	☑		☑	☑	☑		☑	☑
8		☑	☑	☑		☑	☑	☑		☑	☑	34	☑				☑				☑		
9	☑				☑				☑			35		☑	☑	☑		☑	☑	☑		☑	☑
10		☑	☑	☑		☑	☑	☑		☑	☑	36		☑	☑	☑		☑	☑	☑		☑	☑
11		☑	☑	☑		☑	☑	☑		☑	☑	37		☑	☑	☑		☑	☑	☑		☑	☑
12	☑				☑				☑			38			☑				☑			☑	☑
13		☑	☑	☑		☑	☑	☑		☑	☑	39			☑	☑			☑			☑	
14		☑	☑	☑		☑	☑	☑		☑	☑	40		☑	☑	☑		☑	☑	☑		☑	☑
15		☑	☑	☑		☑	☑	☑		☑	☑	41			☑	☑			☑		☑		
16			☑	☑			☑			☑		42					☑		☑		☑		
17		☑	☑	☑		☑	☑	☑		☑	☑	43	☑				☑				☑		
18			☑	☑			☑		☑			44		☑	☑	☑			☑			☑	☑
19				☑			☑		☑	☑	☑	45	☑				☑				☑		
20		☑	☑	☑			☑			☑	☑	46		☑	☑	☑		☑	☑	☑		☑	☑
21	☑				☑				☑			47	☑				☑				☑		
22		☑	☑	☑		☑	☑	☑		☑	☑	48		☑	☑	☑	☑	☑	☑	☑		☑	☑
24	☑								☑			49		☑	☑	☑		☑	☑	☑		☑	
25		☑	☑	☑		☑	☑	☑		☑	☑	50							☑		☑		

Discussion

The study involved determining the equality of the 50 sentence lists of the Matrix Sentence Test in Indian-English (Bhattarai & Yathiraj, 2015) in the presence of speech babble. The results from the 4 participant groups (7 year olds, 8 year olds, 9 year olds, & young adults) are discussed in terms of the effect of age on the sentence identification scores and the equivalence of the 50 sentences lists in the presence of speech babble.

a) Effect of age of the participants on the speech identification scores

The findings of the current study revealed that the 4 age groups studied (7 year olds, 8 year olds, 9 year olds, & young adults) performed in a similar manner on 48 of the 50 sentence lists of the Matrix Sentence test in Indian-English. Only on two of the lists (lists 23 & 33) a significant difference was seen across the age groups. From the outcome of the present study, it can be inferred that 48 sentence lists can be used to determine identification scores in the presence of noise, for both children and adults.

The available literature, on the Matrix sentence tests in different languages, does not provide information regarding the effect of age on speech intelligibility. The majority of these tests were developed for adults (Dietz et al., 2014; Hagerman, 1982; Hochmuth et al., 2012; Houben et al., 2014; Jansen et al., 2012; O'Beirne, 2015; Ozimek et al., 2010; Puglisi et al., 2014; Wagener, Brand, et al., 1999; Warzybok & Zokoll, 2015; Zokoll, Hochmuth, et al., 2012; Zokoll, Wagener, et al., 2012) and have information only on the target age for which the test was developed. A few tests were developed for children such as the Polish Paediatric Matrix Sentence (Ozimek, Kutzner, & Libiszewski, 2012), German Oldenburg Sentence Test for Children (Weisgerber, Baumann, Brand, & Neumann, 2012), and Matrix Sentence Test in Indian-English (Bhattarai & Yathiraj, 2015). While reports are available of the tests being evaluated on children, none of the studies have compared the utility of the Matrix test across children and adults.

The Polish Pediatric Matrix Test (Ozimek et al, 2012) checked for age effect among the target age group (3 to 6 years) for whom the test was developed. The older children among their participants, aged 5 to 6 years, were reported to obtain better scores compared to their younger counterparts, aged 3 to 4 years. This improvement with age in their participants may be attributed to the increasing syntactic and morphological skills in the age group they evaluated. In the current study, changes in performance in the children did not take place as older children were evaluated (7 to 9 year olds). Their language development would have been more stable and not changed as steeply as the younger children studied by Ozimek et al, (2012).

Improvement in performance with increase in age in children has been noted for tests other than those used in the Matrix test. Studies using such sentences report of a significant increase in performance with progressing age (Jamieson et al., 2004; Myhrum, Tvete, Heldahl, Moen, & Soli, 2016). This improvement has been credited to the limited vocabulary and lesser linguistic knowledge in children, relative to adults.

Unlike what has been reported in the literature, the lack of age related changes between children and young adults, seen in the study at hand, can be attributed to the fact that the Matrix sentences in Indian-English was constructed for school-going children. Its linguistic content is based on the vocabulary of children as young as 7 years. As the test material was constructed with young children in mind, older children and young adults would not have had any difficulty in identifying these sentences. This would have been an added reason as to why the performance was similar for the different age groups evaluated in the current study on most of the lists.

Additionally, it has been noted that when a masking noise is used along with speech stimuli, children are affected to a greater extent than adults due to the former age group's immature auditory system. Corbin, Bonino, Buss, and Leibold (2015) document that younger children require more signal to noise ratio, compared to older children and adults, to achieve SNR-50. In the present study an effect of age was probably not seen as the SNR used to establish SNR-50 was higher for the children and lower for the young adults. This variation in SNR was based on a pilot investigation carried out initially to determine SNR-50 on the participants. It was found that children obtained SNR-50 at 0 dB SNR while the adults obtained the same at -5 dB SNR. Thus, the higher SNR used on the children would have enabled them to perform on par with that of the young adults in the presence of noise.

b) Equivalence of lists

The present study revealed that the Matrix sentence test in Indian-English had inter-list equivalency in 37 of the 48 lists that were checked for their similarity in the presence of speech babble. Bhattarai and Yathiraj (2015) observed that in the absence of noise, all 50 sentence lists of their test were equivalent. The 50 lists were reported to be equivalent to each other in terms of their amplitude measures, measured in root mean square values. However, this was found in quiet. The present study, which involved administration of the same material in the presence of noise, yielded 37 equivalent lists and 11 unequal lists (2 lists that varied across the age groups were eliminated). Thus, in the presence of speech babble, only 37 of the lists can be utilized interchangeably.

The reduced coarticulation cues in the Matrix sentence test in Indian-English could be one of the reasons why the lists that were found to be equivalent in quiet, but not equivalent in noise. The material had been developed by splicing of words from sentences to obtain individual words that were later combined to form new sentences. The coarticulatory cues of the initial sentence from which the words were spliced were preserved by cutting words at the zero crossing at the start of the next word. However, the coarticulation cues would not have been appropriate when the words were recombined to form new sentences. Despite this, children were able to perform well in quiet. However, with redundancy further being compromised by a masking noise, the performance of the participants would have deteriorated. The way these coarticulation cues were masked must have varied from one sentence to another. This could have resulted in some of the lists not being equivalent in the presence of noise.

Studies carried out on the Matrix tests have also indicated that not all lists are equivalent. Hagerman (1982) reported that inter-list equivalency was present in 12 out of their 13 lists in the presence of noise. To establish list equivalency, the words in the test were re-grouped to equalize difficulty. Hochmuth et al., (2012) obtained a similar finding with two lists being reported to be unequal. However, these lists were excluded and re-grouping was not considered. Zokoll, Wagener et al., (2012) found that all their lists were equivalent, provided the signals to noise ratio was not favourable. List equivalency was found for -8.5 dB and -11 dB SNR and not found for -6 dBSNR. Similar findings were noted by Dietz et al, (2014), Houben et al, (2014), Warzybok and Zokoll (2015).

Another reason why the 11 lists were unequal could be due to poor scores obtained for certain sentences. Individual data observation revealed consistent poor scores or no scores for specific words, though from different sentences. Diminished scores were greatly noted for the verb category in the sentences. Among the verbs that were used, the words 'wears', 'breaks', 'bought' and 'keeps' were seen to yield poorer scores. Although other word categories also had poor scores, they did not yield poor scores. Hence, it is recommended that sentences having the words 'wears', 'breaks', 'bought' and 'keeps' be eliminated from the 11 lists, as listed in Table 3. It is suggested that the remaining sentences be regrouped after taking into consideration the balance in consonant distribution within each list as recommended by Bhattarai and Yathiraj (2015). By doing so a new set of lists can be developed that will yield equivalent responses in the presence of speech babble.

Conclusions

From the findings of the study it can be seen that 48 of the 50 sentences in the Matrix Sentence Test in Indian-English yielded similar performance across the three groups of children and young adults who were evaluated. Thus, these lists can be used for evaluating speech intelligibility of both children and adults. It was found that in the presence of noise, 37 of the lists were equivalent and 11 were unequal. Of these 48 sentences, 37 lists can be used interchangeably in the presence of noise. Further, it was found that among the 11 lists that were found to unequal, the participants obtained poor scores on a specific words.

Hence, it is recommended that sentences having these words be removed from the material and the remaining sentences be regrouped after taking into consideration the balance in consonant distribution within each list to form a new set of lists that will yield equivalent responses in the presence of speech babble.

Table 3: List of sentences with poor word scores, from the 11 unequal lists

List 2	*List 36*
'Krishna took one green hat'	'Chetan wants five new flowers'
'Priya breaks five red pens'	*List 37*
'Raja wears some old socks'	'Usha breaks many big toys'
List 10	*List 40*
'Preeti bought ten good dress'	'Sita got five new books'
'Krishna saw twelve small toys'	'Sita wants twelve small toys'
'Sita wears some old socks'	'Preeti keeps five new bags'
List 17	*List 40*
'Sita breaks twelve small toys'	'Sita got five new books'
'Usha wears five small socks'	'Sita wants twelve small toys'
List 32	'Preeti keeps five new bags'
'Usha got five new books'	*List 45*
'Priya bought four red bags'	'Prema breaks twelve small toys'
'Prema bought twelve small toys'	*List 46*
List 34	'Prema breaks three long toys'
'Chetan took five new books'	'Sita got five new books'
'Preeti took four red bags'	*List 49*
'Krishna saw some clean flowers'	'Krishna saw five new pens'

Thus, based on the findings of the study it can be concluded that the Matrix Sentence Test in Indian-English, when presented in the presence of noise, can be used for both children and adults. Several of the lists are equivalent can be used interchangeably.

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