EQUIVALENCE OF THE MATRIX SENTENCE TEST IN INDIAN-ENGLISH IN THE PRESENCE OF NOISE

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This Dissertation is submitted as part of fulfillment for the Degree of Master of Science in Audiology

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CERTIFICATE

This is to certify that the dissertation entitled "**EQUIVALENCE OF THE MATRIX SENTENCE TEST IN INDIAN-ENGLISH IN THE PRESENCE OF NOISE"** is the bonafide work submitted in part fulfillment for the degree of Master of Science (Audiology) of the student (Registration No. 14AUD015). This has been carried out under the guidance of a faculty of this institute and has not been submitted earlier to any other University for the award of any other Diploma or Degree.

Mysuru,
May, 2016.

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Mysuru,
May, 2016

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DECLARATION

This is to certify that this dissertation entitled "**EQUIVALENCE OF THE MATRIX SENTENCE TEST IN INDIAN-ENGLISH IN THE PRESENCE OF NOISE"** is the result of my own study under the guidance of **Dr. Asha Yathiraj**, Professor in Audiology, Department of Audiology, All India Institute of Speech and Hearing, Mysore and has not been submitted earlier to any other University for the award of any other Diploma or Degree.

Mysuru,
May, 2016

Registration No: 14AUD015

DEDICATION

This dissertation is dedicated to the sculptors of my life.

To my Amma, for being my first teacher-my role model, a strong and gentle soul, who taught me to trust in God, believe in hard work and for supporting & encouraging me to believe in myself; to my Pappa, for all his support along the way; & to all my well-wishers.

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"I would maintain that thanks are the highest form of thought; and that gratitude is happiness doubled by wonder."

-G.K. Chesterton

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Abstract

Objective: 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 in children and young adults.

Introduction: 'The Matrix Sentence Test in Indian-English' contains 50 lists that are reported to be equivalent in a quiet situation. Its equivalence in the presence of noise had not been established at the time of construction. As children are often exposed to speech in the presence of noise, evaluating their speech identification in the presence of noise would enable determining their performance in a real life situation.

Study sample: A purposive sampling technique was used to select the participants. The study was conducted in two stages. A pilot investigation was done, on 5 normal hearing, school-going children and 5 normal hearing young adults. A constant stimuli paradigm was used wherein the sentences were presented at a constant level equivalent to normal conversation (45 dB HL) and the noise was varied to establish SNR-50. The eight-talker speech babble developed by Yathiraj, Vanaja and Muthuselvi (2009) was used as the noise. The second stage involved evaluating SNR-50 on 60 participants. These participants were divided into four age groups with 10 individuals each in the younger 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.

Results: 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. The lists, 23 and 33 that were found to have an age effect were eliminated from further analyses. Further, it was found that 37 lists were equivalent to each other and 11 lists were unequal, in the presence of noise.

Conclusions: 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 that yielded poor scores.

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Chapter 1

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 fixed 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, 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 a 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 using 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), on the other hand, was developed only as a suprathreshold measure to track speech identification. However, the authors recommended that further research needs to be carried out to check the ultility of the test in the presence of noise.

1.1. Need for the Study

The Matrix Sentence Test in Indian-English has been developed to provide information about difficulties in perception faced by children in real life situations. The majority of the matrix sentence tests have been designed to assess speech recognition in the presence of noise [Swedish Matrix Test (Hagerman, 1982); Polish Matrix Test (Ozimek et al., 2010); German Matrix Test (Wagener, Brand, et al., 1999); Spanish Matrix Test (Hochmuth et al., 2012); Turkish Matrix Test (Zokoll, Hochmuth, et al., 2012); French Matrix Test (Jansen et al., 2012); Italian Matrix Test (Puglisi et al., 2014); Finnish Matrix Test (Dietz et al., 2014); American-English Matrix Test (Zokoll, Hochmuth, 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)]. However, these tests were assessed on individuals above the age of 16 years.

Although there are reports that a matrix test is developed and tested in the presence of noise in children as young as 3 to 6 years (Ozimek et al., 2012), it has been administered using a simpler version of the test. The Polish Pediatric Matrix Sentence Test, developed by Ozimek et al, (2012) utilized 3-word sentences comprising of a 'subject', 'verb' and 'object' unlike the standard 5 word-matrix sentences that uses 'name', 'verb', 'number', 'adjective', and an 'object'. Thus, there is no Matrix test for children that uses the standard sentence paradigm to evaluate speech intelligibility in the presence of noise. While the Matrix Sentence Test in Indian-English (Bhattarai & Yathiraj, 2015) was developed for children, 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 equivalance of material in quiet is not similar to that in the presence of noise. 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.

1.2. Aim of the study

The study aims 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.

1.3. Objectives of the study

The objectives of the study are as follows:

- To compare the performance of the normal hearing young children with the young adults on the Matrix Sentence Test in Indian-English (Bhattarai & Yathiraj, 2015).
- To check the equivalence of the 50 sentence lists of the 'Matrix Sentence Test in Indian-English' (Bhattarai & Yathiraj, 2015) in the presence of noise in normal hearing children aged 7 to 10 years and young adults aged 18 to 25 years.

Chapter 2
Review of Literature

Sentences are reported to provide better phoneme representativeness, steeper intelligibility functions and more accurate identification scores when compared to other stimuli to assess speech perception such as words, nonsense syllables and phonemes (Plomp & Mimpen, 1979; Kollmeier, 1997; Ozimek, Warzybok, & Kutzner, 2010). Evidence from literature has shown that sentences with a conventional structure yielded better intelligibility scores than sentences with unpredictable structure (Hagerman, 1982; Hochmuth et al., 2012; Puglisi et al., 2014).

Speech identification testing, especially in the presence of background noise, is considered essential as typically developing children often tend to have difficulty understanding speech amidst competing stimuli. School-going children are required to perceive instructions from teachers in the presence of certain background noises such as children talking to each other or/and rattling pages (Jamieson, Kranjc, Yu, & Hodgetts, 2004). Conditions like these, apart from the conventional noise involved in daily life activities, have made it vital to have a test that can tap sentence perception in the presence of noise. Mendel and Widner (2015) reported that the interfering or competing masker will degrade the signal and affect bottom-up processing cues that are beneficial for accurate speech perception, regardless of the type of masker. Background noise in assessing speech intelligibility is considered to enhance cognitive load, particularly working memory.

2.1. SNR-50

Studies have used different techniques to assess perception of speech in the presence of noise. One such technique is determining SNR-50. In this technique, the presentation level of the sentences are kept constant and the intensity of the noise is varied to establish the highest intensity level of noise at which 50% of the sentences can be correctly identified. This procedure was first described by Hagerman (1982). The term SNR-50, however, was not used by them.

McArdle et al, (2005) found that speech recognition was better for digits, when compared to words and sentences, in the presence of multitalker babble. The authors reported of a factor, termed as distortion factor that affects the ability to recognize speech in background noise. This distortion factor was considered to either be peripheral or central. Peripheral distortion was considered to occur because of increased bandwidths leading to poorer frequency resolution. Central distortion, on the contrary, was considered to occur due to age related changes affecting the central nervous system. McArdle et al, (2005) documented the average speech-to-babble ratio, at SNR-50, to be 2 to 6 dB for normal hearing individuals and 10 to 12 dB for individuals with hearing impairment. This highlighted the fact that individuals with hearing impairment not only have a loss of pure-tone sensitivity but a loss of signal versus noise as well that is, a decline in signal-to-noise ratio. This was termed as SNR loss by Killion, Niquette, Gudmundsen, Revit, and Banerjee (2004), which is defined as the amount of enhancement in signal relative to noise required to achieve 50% correct intelligibility scores. Without possessing the knowledge of SNR loss, they opined that it was virtually not feasible to give realistic expectations for potential improvement in noise with amplification.

Knowledge of SNR loss has been considered beneficial with respect to recommending amplification modifications such as omni-directional microphones, directional microphones, array microphones and close talking FM microphones (Killion et al., 2004). As SNR loss cannot be predicted from objective measures in quiet, McArdle et al. (2005) recommend the use of sentence tests in noise. This is suggested to help select amplification strategies, corroborating patient’s claim of activity limitations, counseling concerns and the likes.

It has been noted that SNR-50 scores varied depending on the age of an individual. Corbin, Bonino, Buss, and Leibold (2015) reported that younger children aged 5 to 13 years were found to require more signal relative to noise than older children aged 13 to 16 years and adults to reach SNR-50. The study involved presentation of monosyllabic words as stimuli in the presence of two types of maskers, a speech shaped noise and a two talker babble. Open set responses were established for speech recognition. Across all ages, responses were poorer in the presence of the two-talker babble as the masker, relative to the speech shaped noise. However, developmental trajectories were reported to vary among these two types of maskers. For the speech shaped noise as the masker, performance steeply increased until 10 years of age and achieved a plateau thereafter. On the contrary, for the two-talker babble, a gradual improvement in scores was seen up to 13 year old subjects and an abrupt steep leap in scores for ages above 13. The authors document this finding to delineate the importance of considering age and type of masker prior to administering speech recognition tests in noise.

SNR-50 has been established using different test material. One test material that has been used to establish is the Matrix sentence test. These sentence tests have been developed and used in different languages.

2.2. The Matrix Sentence test

The different versions of the Matrix sentence test have been utilized with and without the presence of noise. The Matrix sentences, originally developed by Hagerman (1982), was developed such that it had low redundancy despite being syntactically fixed. The sentences for the tests were constructed using a base matrix that included five categories (name, verb, numerical, adjective, & object), each containing 10 words. This test, developed in Swedish was titled 'Sentences for Testing Speech Intelligibility in Noise'. This test was designed with the intention of developing speech intelligibility material for evaluation of hearing aids in free-field and discrimination under headphones. The aim was to produce different sentence lists with equal difficulty and reliable results. The key benefit reported about the Matrix sentence test was that it is difficult to remember the sentences because of their lower redundancy that allows testing the same individual several times with different hearing aids in single or multiple sittings (Hagerman, 1982). The performance on these sentences has been evaluated in different languages in quiet as well as in noise. The performance has been evaluated mainly in adults, however a few reports are provided about the performance of children.

2.2.1. Use of the Matrix Sentences in the presence of noise

Sentence tests in noise were noted to be the stimuli that presented a ballpark figure of the difficulties bothering individuals in realistic situations. Testing sentence perception in the presence of noise has been widely used (Corbin et al., 2015; Jain et al., 2014; Jamieson et al., 2004; Killion et al., 2004; Levy et al., 2015; McArdle et al., 2005; Turner & Henry, 2002; Tyler, 1994). The Matrix sentence test originally developed by Hagerman (1982) was designed to evaluate speech discrimination in the presence of noise. Hence, noise was generated by periodic filtering the sounds of the original word list, to make 7 periodic noises with periodicities between 10 and 30 Hz. The 7 periodic noises were mixed together to form a noise with no obvious periodicity but having the accurate spectral attribute as the word lists. To make the noise not have a steady state, but to sound like cocktail-party noise, a low frequency amplitude modulation was introduced. The Matrix test has been developed in several languages with slight variations in them. Table 2.1 provides a summary of these tests, mentioning the number of sentences that are used, the age groups for which it is developed, the mode of eliciting responses and the evaluation carried out in each of the tests.

Table 2.1

Matrix sentences tests administered in the presence of noise

Author(s)	Name of the test and language of administration in parenthesis	Number of sentences	Type of back ground noise	Age group tested	Mode of Response	Evaluation carried out
Hagerman (1982)	Sentences for Speech intelligibility in noise (Swedish)	13 lists (10 sentences per list)	Amplitude modulated synthetic noise	Adults (18 to 32 years)	Open set verbal responses	Discrimination at SNR-50
Wagener, Brand, et al, (1999)	Evaluation of the Oldenburg Sentence Test (German)	----	Speech matched synthetic noise	Adults (age range not given)	Open set and closed set responses	Speech Reception Threshold estimated at SNR-50
Hewitt (2008)	Evaluation of an English Speech in noise Test (British-English)	----	Speech matched synthetic noise	Adults (age range not given)	Open set and closed set responses	Speech Reception Threshold estimated at SNR-50
Ozimek et al, (2010)	Sentence matrix test for speech intelligibility in noise (Polish)	10 lists (20 sentences per list)	Speech noise	Adults (age range not given)	Closed and open set responses	Speech Recognition thresholds obtained at SNR-50
Zokoll, Wagener, et al, (2012)	US Matrix Sentence Test in Noise (American-English)	250 sentences	Speech matched synthetic noise	Adults (age range not given)	Closed and open set responses	Speech Recognition thresholds obtained at SNR-50
Hochmuth et al, (2012)	Spanish matrix sentence test (Spanish)	12 test lists of 10 sentences each combined to 6 double lists of 20 sentences	Spectra matched non-fluctuating synthetic noise	*i.*Adults (18 to 48 years) *ii.*Adults (22 to 32 years)	*i.*Open set verbal responses *ii.*Closed set clicking responses	Responses obtained at SNR-80 and SNR-20 using fixed SNRs of -4, -5 and -9 dB.

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Zokoll, Hochmut et al, (2012)	Turkish Matrix Test (Turkish)	30 lists (10 sentences per list)	----	Adults (21 to 36 years)	Open set verbal responses	Test optimised in presence of noise for SRT and speech intelligibility scores.
Jansen et al, (2012)	French speech in noise test (French)	50 lists (10 sentences per list)	Spectrum matched synthetic noise	Adults (20 to 29 years)	Open set verbal responses	SRT was estimated.
Houben et al, (2014)	Dutch matrix sentence test (Dutch)	14 lists (20 sentences per list)	----	Adults (19 to 26 years)	Open set responses	Measured interlist deviance. Optimisation and validation done.
Puglisi et al, (2014)	Italian Matrix Sentence Test for speech intelligibility in noise (Italian)	6 double lists of 20 sentences overall	----	Individuals aged 16 to 37 years	Open set and closed set responses	SRT measured at SNR-50
Dietz et al, (2014)	Finnish Matrix Sentence Test (Finnish)	30 lists (10 sentences per list)	Spectrum matched synthetic noise	Adults (21 to 38 years)	Open set responses	Adaptively measured SRT at five SNR levels (-2, -4, -16, -18 and -20 dB). Fixed noise level at 65 dBSPL
O'Beirne, (2015)	Auditory-visual Matrix Sentence Test (New Zealand-English)	30 lists (20 sentences per list)	Speech shaped noise and six-talker babble	Adults (21 to 28 years)	Closed set and open set responses	Word scoring. SRT at SNR-50 was obtained.
Warzybok and Zokoll (2015)	Russian matrix sentence test (Russian)	16 lists (10 sentences per list)	Synthesized by superimposition of sentences	Adults (19 to 33 years)	Closed set responses and open set responses	SRT at SNR-50 was obtained
Buschermöhle, Zokoll, Abdulhaq, Hochmuth and Kollmeier (n.d.)	The Arabic Matrix Test (Arabic)	----	Spectrum matched synthetic noise	Adults (age range not given)	Closed set and open set responses	Speech Reception Thresholds obtained at SNR-50.

2.3. Applications of Matrix Sentence Tests in Noise

The Matrix test has been adapted to several languages and utilized for varied purposes, with results comparable when measuring speech identification in the presence of noise (Wagener, Zokoll, Berg, Jansen, & Lyzeng, 2009). Studies have reported of the Matrix test being used for establishing speech reception thresholds and determining speech identification scores in children and adults, evaluate performance as a function of age, and establish the performance of children using devices such as cochlear implants.

The Matrix sentence tests, with syntactically similar and semantically unpredictable sentences, have shown superior accuracy and reliability compared to natural sentences. It is reported that the sentence lists can be repeatedly used with the same subject due to their unpredictability and complexity. These tests are hence, recommended for research studies involving extensive measurements (Hagerman, 1982; Puglisi et al., 2014; Wagener et al., 2003).

The Polish Paediatric Matrix Sentence Test was evaluated on normal-hearing children and children with hearing impairment aged 3 to 6 years by Ozimek et al, (2012). The results showed that as age increased, SRT was better. They also observed that children with hearing impairment had poorer SRT compared to normal hearing children in all age groups. The authors concluded that the Polish pediatric matrix sentence test, if pooled with a picture pointing task could be a consistent tool for estimating speech intelligibility in the pediatric population.

Hochmuth et al. (2012) recommended the use of an adaptive tracking procedure in combination with their own Spanish matrix sentence test that can establish a favourable SNR at a higher recognition rate (greater than 80%). This inturn was said to yield threshold values at better signals to noise ratios. Wagener and Kollmeier (2005) recommend considering an abbrievated version of the test using only the last three words of a sentence (numerical, adjective and object) for much younger children or even adults with a reduced cognitive listening span.

The German Matrix Test (Wagener, Brand, et al., 1999) titled, 'The Oldenburg Sentence Test in noise', was used to evaluate cochlear implant users by Hey, Hocke, Hedderich and Müller-Deile (2014). Speech reception thresholds were measured at various signal-to-noise ratios to determine the slope of discrimination function per subject. The slope of the discrimination function reduced considerably for poorer cochlear implant performers. It was found that test-retest reliability showed a significant dependence on speech recognition threshold in noise. Better the SRT, narrower was the difference noted between test and retest trials. They added that even well trained implant wearers required procedural learning prior to matrix sentence test administration. A fixed SNR reduced the fatigue effect and yielded considerable reproducibility.

Theelen-van den Hoek, Houben and Dreschler (2014) evaluated the Dutch matrix sentence test in 15 post-lingual cochlear implant users in quiet and in noise. They also investigated the possibility to improve the test-retest reliability for cochlear implant users by selecting subsets of sentences. Speech intelligibility testing was repeated in quiet and in noise. A cross-over design was used to see the effect of selection of sentences on the test-retest reproducibility. Improvement was predicted in test-retest reliability in quiet, by computer simulations. The results suggested that homogeneity of the sentences was not the primary factor that would influence test-retest reliability. There was no significant difference found between the Dutch matrix sentences and the selected subsets of sentences. It was found that both these stimuli were equally suitable for testing speech intelligibility in cochlear implant users. The authors conclude that, though the test efficiency was slightly less favorable to cochlear implant users compared to normal hearing listeners, the Dutch Matrix sentence test can be widely used for a large sample of cochlear implant users. Although the computer simulations suggested that selection of sentences can effectively increase homogeneity of the sentences, the test-retest reliability or the steepness of the intelligibility functions for the cochlear implant users did not improve.

The influence of the type of masker noise on the speech recognition thresholds using matrix sentence tests of four different languages was checked by Hochmuth, Kollmeier, Brand and Jürgens (2015). German, Spanish, Russian and the Polish matrix sentences were tested on 40 subjects (ten native speakers of each of the four languages). The maskers used were six stationary speech-shaped noises and three non-stationary noises. It was found that significant differences in speech reception thresholds were obtained when stationary noise that matched the long-term frequency spectrum of the speech material was used. Differences in speech reception thresholds, because of the interference of the masker, were also found for the other stationary noises. However, these differences were not found to be significant. For the fluctuating noises, it was observed that the benefit with speech reception threshold was slightly smaller for the Spanish test, while it was similar to the other tests. Speech reception thresholds were found to be elevated by 3 dB for the German and Spanish tests, relative to the Russian and Polish tests. Test-retest reliability was found to be varied across noise conditions between languages. The authors concluded that speech reception threshold differences between languages and among different noise maskers can be attributed to differences with reference to spectrum. The findings of this study assist in providing feasibility and limits of comparing results across languages.

Kollmeier et al, (2015) reviewed the Matrix sentence tests of 14 languages for speech intelligibility testing in a multilingual society. Sentences in all the 14 tests were optimised prior to administration. Influence of the talker, language of the test, masking noise, the training effect, open vs. closed conduct of the test, and the subjects' language proficiency were observed on the speech intelligibility function. The effect of the masker was found to fall in line with Hochmuth et al, (2015)'s findings with the fluctuating masker noise yielding better speech reception thresholds compared to static noises. Training effects were seen for each language, within the first few test runs, for both the open-set and the closed-set tasks. Better training effects were observed for the closed-set task. Irrespective of the training given, closed-set responses yielded better speech recognition thresholds, compared to open-set responses. Twelve language tests showed significant speech reception thresholds differences across the test formats. However, for the Polish and the German tests, no significantly different responses were obtained. Across languages, comparison was found to be very limited as the effects of the language and the talker could not be compared with each test recorded by a different talker. Effects of the talker and the language were ideally separated by using same talkers for different languages, or bilingual talkers. For all of the German-Russian talkers, no statistical differences in speech reception thresholds between languages were found. The main difference in performance across languages was observed, as a result of employing a different talker for each language. Only small differences were observed between languages with the same talker when a bilingual talker was employed (up to 3-dB difference). Normalization across languages revealed that stationary test-specific noises yielded small differences between the various languages, mainly due to talker differences. Larger differences were observed for other types of maskers such as fluctuating noise. However, the authors concluded that in general, the variation across languages seemed smaller than across talkers.

From the review, it can be inferred that matrix sentence tests have a vital application in tapping recognition in the presence of noise. Most matrix sentence tests have been administered in the presence of noise but largely on individuals above the age of 16 years. Only one matrix sentence test has been reported to be developed to test children in the presence of noise (Ozimek et al., 2012). However, this test used a simpler version of the test having three word sentences comprising of ‘subject’, ‘verb’ and ‘object’. While the Matrix Sentences in Indian-English (Bhattarai & Yathiraj, 2015) was developed for children using a standard five-word format, its utility was not tested in the presence of noise, simulating a realistic situation. Thus, the literature shows that there is limited use of the Matrix sentence test on children.

Chapter 3

Methods

The study aimed to determine the equality of the Matrix Sentence Test in Indian-English (Bhattarai & Yathiraj, 2015) in the presence of noise. Using a purposive sampling technique, 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.

3.1. Participants

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 and the young adults were fluent speakers of the language with a minimum of 5 years of exposure to it in an educational institution.

3.2. 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. 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 et al, (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, for each sentence. The noise segments were normalized in amplitude to the specific sentence sample. Each noise segment starts 500 ms before the sentence and ends 500 ms after the sentence.

3.3. 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. Institute of Laryngology and Otology, version 6 (ILOv6) was used to estimate otoacoustic emissions in all participants to rule out outer hair cell abnormalities. 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).

3.4. 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).

3.5.1. Stage 1: Pilot Experiment

In order to estimate the appropriate and optimal signal-to-noise ratio, 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 was done to determine 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.

3.5.2. 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. Participants were included in the study if they had pure-tone thresholds less than 15 dB HL in both ears at 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.

A written consent was taken from each participant or caregiver preceding their inclusion. This was done after briefing them about the details of the test procedure and the purpose of the study.

Procedure for administration of sentence-in-noise test:

The sentence test developed by Bhattarai and Yathiraj (2015) 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 which 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.

3.6. 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 f_x) facility of the spreadsheet was used to calculate the total score per list.

3.7. 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.

Chapter 4

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. Descriptive and inferential statistical analyses were carried out using SPSS software (version 17.0). At the outset, a Shapiro-Wilk test of normality was used to check if the data were normally distributed. The results of the Shapiro-Wilk test revealed that the responses of many of the lists did not have normal distribution. This was seen for all four age groups. Hence, the data were analysed using nonparametric statistics. Further, to check for the presence of any outliers, a box plot was drawn. 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.

The effect of age on speech identification scores in noise was evaluated using a Kruskal-Wallis test and the inter-list equivalency was evaluated with the help of Friedman's and Wilcoxon signed ranks tests. Details of age effect and inter-list equivalency are provided below.

4.1 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 [χ (3) = 8.878, $p < 0.05$] and List 33 [χ (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.

4.2. 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, nonparametric 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 [χ (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 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 [χ (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 not equivalent in the presence of speech babble are listed in Table 4.1. Details of the 37 equivalent lists and the 11 unequal lists are given in Appendix I.

Table 4.1

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).

Sentence Lists No.	Mean	Median	SD	Sentence Lists No.	Mean	Median	SD
List 1[≈]	25.45	26	3.31	List 26[≈]	24.63	25	2.7
List 2[#]	23.77	24	2.54	List 27[≈]	24.27	24	1.93
List 3[≈]	24.45	24	2.01	List 28[≈]	24.82	24	2.24
List 4[≈]	24.7	25	2.57	List 29[≈]	24.46	24	2.34
List 5[≈]	24.27	24	2.53	List 30[≈]	24.38	24	2.04
List 6[≈]	24.54	24	2.2	List 31[≈]	24.52	25	2.06
List 7[≈]	24.73	24	2.81	List 32[#]	25.63	25	2.31
List 8[≈]	25.16	25.5	2.67	List 34[#]	23.84	24	2.34
List 9[≈]	24.48	24.5	2.46	List 35[≈]	25.64	25	2.89
List 10[#]	25.86	25	2.6	List 36[#]	26	26	2.25
List 11[≈]	25.23	25	2.78	List 37[#]	25.61	26	2.48
List 12[≈]	24.38	24	2.68	List 38[≈]	25.14	25	2.49
List 13[≈]	25.21	24	2.33	List 39[≈]	25.04	24.5	2.81
List 14[≈]	25.71	25	3.09	List 40[#]	26	25	2.53
List 15[≈]	25.38	26	2.29	List 41[≈]	24.8	24	2.53
List 16[≈]	24.98	25	2.09	List 42[≈]	24.75	24	2.57
List 17[#]	25.57	25	2.09	List 43[≈]	24.46	24	2.22
List 18[≈]	24.8	25	2.51	List 44[≈]	25.16	25	2.18
List 19[≈]	24.86	25	2.37	List 45[#]	24.18	24	2.37
List 20[≈]	25.04	25	2.03	List 46[#]	25.79	25	2.57
List 21[≈]	24.36	24.5	2.35	List 47[≈]	24.39	24	2.16
List 22[≈]	25.27	25	2.35	List 48[≈]	25.2	25	2.6
List 24[≈]	24.55	24.5	2.21	List 49[#]	25.8	25	2.58
List 25[≈]	25.52	25	3.25	List 50[≈]	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
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 4.1) that were significantly different from the 37 other lists that were equivalent (represented by ≈ in Table 4.1). This pair-wise test was done to check if they are significantly different from the other lists. The z and *p* values of the Wilcoxon signed ranks test are provided in Appendix II. The lists with which these 11 lists were found to be equivalent with are provided in Table 4.2.

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 4.2.

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							☑		☑		

Chapter 5

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.

5.1 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). Reports are available of the tests being evaluated on children. None of the studies have compared the utility of the Matrix test across different age groups.

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 involving 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.

5.2 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, were 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 the masker 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 unequivalent. 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 was found for -8.5 dB and -11 dBSNR 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 significantly poor scores. Hence, it is recommended that sentences having the words ‘wears’, ‘breaks’, ‘bought’ and ‘keeps’be eliminated from the 11 lists that are listed in Table 5.1. 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.

Table 5.1

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

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

Chapter 6

Summary and Conclusions

Matrix Sentence Tests, reported in literature, were mainly administered for individuals older than 16 years. Relatively few Matrix sentence tests have been developed for children (Bhattarai & Yathiraj, 2015; Ozimek et al., 2012). The test developed by Ozimek et al, (2012) did not follow the standard structure paradigm of matrix sentencses. On the other hand, the Matrix Sentence Test in Indian-English was developed following the standard 5-word matrix sentence structure to evaluate speech intelligibility in school-going children aged 7 to 10 years. However, this test was evaluated only in a quiet condition. With school-going children being prone to adverse listening situations such as classroom noise, there is a need to evaluate their performance in the presence of noise.

The primary aim of the present study was, thus, to determine the equality of the 50 lists of the Matrix Sentence Test in Indian-English (Bhattarai & Yathiraj, 2015) in the presence of speech babble. This was evaluated on typically developing, school-going children aged 7 to 10 years, with a minimum exposure of 3 years to English. Their performance was compared to that of young adults aged 18 to 25 years, to check for an age effect on identification scores. The material developed by Bhattarai and Yathiraj (2015) was presented to 60 participants, divided into four 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 young adults (18 to 25 years)]. A purposive sampling technique was used to select the participants.

An eight-talker babble, developed by Yathiraj et al, (2009) was used as an ipsilateral masker. Initially, a pilot study was conducted to establish the level of noise required for the participants to get 50% responses when the signal was presented at a constant signal level of 45 dB HL. SNR-50 for the Matrix Sentence Test in Indian-English was obtained at 0 dB SNR and -5dB SNR for children and adults, respectively. Each participant listened to all 50 lists of the Matrix Sentence Test in Indian-English in a random order through headphones and their open-set responses were noted. A score of one was given, for every correct word that was repeated.

As a Shapiro-Wilk test of normality revealed that several of the sentence lists were not normally distributed, the data were analysed using nonparametric statistical tests. To check for the effect of age over identification scores, Kruskal-Wallis test was done and it revealed no effect of age for 48, of the 50 sentence lists. The two lists, found to be significantly different across the age groups, were eliminated before carrying out further analyses.

Equivalency of the 48 sentence lists to each other was determined by administration of a Friedman’s test. It was found that in the presence of noise, 37 of the lists were equivalent and 11 were unequal. It can be concluded that 48 of the 50 lists can be used for evaluating speech intelligibility of both children and adults. 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 group of words (‘wears’, ‘breaks’, ‘bought’ , and ‘keeps’). Hence, it is recommended that sentences having these words appearing be removed from the material. It is suggested that 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.

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 and can be used interchangeably.

Implications of the study:

The Matrix Sentence Test in Indian-English in the presence of noise would be useful in the following ways:

- The test lists can be used to study sentence identification in the presence of noise on both children and adults.
- The test can serve as a comprehensive diagnostic tool to tap a wide variety of speech identification difficulties in individuals with hearing impairment, especially in the presence of background noise.

- The scores can be used to give a feedback to individuals regarding the difficulties they will face in a real life situation.
- The sentences can be used for the selection of hearing aids.
- The material can be used to test outcome of devices like hearing aids and cochlear implants.
- The test scores can be used to make judgment about the rehabilitation procedure that can be used by the individuals. In addition, the test can help keep track of the rehabilitation by comparing pre- and post-test scores. Maintenance of the scores established can also be tracked.

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Appendix

Appendix I:

Equivalent and Non-equivalent lists of the Matrix Sentence Test in Indian English in the presence of noise

Equivalent Sentence Lists	Non-equivalent Sentence Lists
◦ *List 1*	◦ *List 2*
1. Preeti saw some clean flowers	1. Raja wears some old socks
2. Rahul saw many big balls	2. Priya breaks five red pens
3. Priya saw many big balls	3. Prema breaks ten old toys
4. Prema saw one green hat	4. Raama took ten good books
5. Raama saw five new pens	5. Sita wants many big balls
6. Sita bought many big balls	6. Krishna took one green hat
7. Krishna washed five small socks	7. Chetan took three blue pens
8. Raja washed twelve red bags	8. Usha keeps some clean flowers
9. Chetan bought four red toys	9. Krishna saw six old bags
10. Preeti wants four red bags	10. Usha sings three old songs
◦ *List 3*	◦ *List 10*
1. Preeti saw one green hat	1. Preeti bought ten good dress
2. Raja saw four red balls	2. Priya wants many big balls
3. Priya saw some clean flowers	3. Prema bought some clean flowers
4. Sita saw five new pens	4. Raama keeps three blue pens
5. Krishna breaks five big toys	5. Sita wears some old socks
6. Chetan took five new books	6. Krishna saw twelve small toys
7. Usha breaks five big toys	7. Chetan saw one green hat
8. Preeti wants many big bags	8. Rahul saw three blue bags
9. Chetan washed some old socks	9. Raja wants four red bags
10. Usha sings ten old songs	10. Usha took six old songs
◦ *List 4*	◦ *List 17*
1. Preeti washed six long dress	1. Preeti wants ten good dress
2. Rahul saw five new books	2. Raja washed some old socks
3. Raja saw many big toys	3. Priya took some clean flowers
4. Priya saw four red balls	4. Prema wants many big balls
5. Prema wants one green hat	5. Sita breaks twelve small toys
6. Raama bought some clean flowers	6. Krishna bought one green hat
7. Sita washed some old socks	7. Chetan took ten good books
8. Krishna saw five new pens	8. Usha wears five small socks
9. Raja saw twelve small bags	9. Prema sings some old songs
10. Usha sings some old songs	10. Raama took ten good songs
◦ *List 5*	◦ *List 32*
1. Preeti bought some clean flowers	1. Prema bought twelve small toys
2. Rahul washed some old socks	2. Raama got many big balls
3. Priya bought three blue pens	3. Usha got five new books
4. Prema bought one green hat	4. Prema wants four red toys
5. Raama bought five new books	5. Raama wears some old socks
6. Krishna saw many big toys	6. Krishna got some clean flowers
7. Chetan saw four red balls	7. Preeti took some clean bags
8. Raja saw many big bags	8. Priya bought four red bags
9. Rahul bought ten good dress	9. Sita sings four old songs
10. Usha took twelve small toys	10. Usha wants some clean flowers

Continued..

Continued..

◦ *List 6*

1. Preeti washed some old socks
2. Rahul saw one old hat
3. Priya got five new books
4. Prema got many big balls
5. Raama bought three blue pens
6. Krishna saw some clean flowers
7. Chetan saw many big toys
8. Rahul took one green hat
9. Raja saw four red bags
10. Sita took ten good songs

◦ *List 7*

1. Preeti wants many big balls
2. Usha breaks twelve small toys
3. Priya breaks ten old toys
4. Prema got some clean flowers
5. Raama wants three blue pens
6. Sita took ten good books
7. Krishna bought five new books
8. Chetan saw four red bags
9. Raja wants three blue bags
10. Usha sings six old songs

◦ *List 8*

1. Preeti got ten good dress
2. Rahul took ten good books
3. Raja got three blue pens
4. Priya bought many big balls
5. Prema washed some old socks
6. Krishna saw one green hat
7. Chetan saw some clean flowers
8. Usha took ten good bags
9. Sita sings twelve old songs
10. Rahul wants six old bags

◦ *List 9*

1. Chetan bought five new books
2. Rahul took many big balls
3. Priya got four red toys
4. Prema washed some old socks
5. Raama breaks four old pens
6. Sita saw some clean flowers
7. Krishna took ten good books
8. Chetan wants twelve small bags
9. Raja wants twelve small bags
10. Priya keeps some clean flowers

◦ *List 11*

1. Preeti washed six long dress
2. Rahul took some clean flowers
3. Priya washed five small socks
4. Prema keeps five new books
5. Usha sings four old songs

◦ *List 34*

1. Rahul wants one green hat
2. Raja keeps some clean flow
3. Priya keeps twelve small to
4. Prema took four red toys
5. Krishna saw five clean flowers
6. Sita sings many old songs
7. Chetan took five new books
8. Usha took many big balls
9. Preeti took four red bags
10. Krishna saw some clean flowers

◦ *List 36*

1. Chetan took four red toys
2. Prema got one green hat
3. Sita keeps many big balls
4. Sita keeps four red toys
5. Chetan wants five new flowers
6. Sita keeps twelve small toys
7. Preeti keeps four red bags
8. Preeti wants some clean bags
9. Rahul saw four red bags
10. Sita sings some old songs

◦ *List 37*

1. Preeti got ten good dress
2. Rahul took ten good books
3. Raja got three blue pens
4. Raja keeps one green hats
5. Prema took five clean flowers
6. Raama washed some old socks
7. Sita took many big balls
8. Usha breaks many big toys
9. Preeti wants six old bags
10. Sita sings ten old songs

◦ *List 40*

1. Rahul wears one clean dress
2. Raja got one green hat
3. Prema took some clean flowers
4. Raama wears some old socks
5. Raama took three blue pens
6. Sita got five new books
7. Sita wants twelve small toys
8. Usha got many big balls
9. Preeti keeps five new bags
10. Priya sings six old songs

◦ *List 45*

1. Preeti wears some old socks
2. Prema breaks twelve small toys
3. Sita wants one green hat
4. Chetan took ten good books
5. Preeti wears six long dress

Continued..

Continued..

6. Raama took twelve small toys
7. Sita took three blue pens
8. Krishna bought many big balls
9. Chetan bought one green hat
10. Usha wants six old songs

° *List 12*

1. Rahul wants many big balls
2. Raja took one green hat
3. Priya took ten good books
4. Raama keeps some clean flowers
5. Chetan got three blue pens
6. Krishna bought four red toys
7. Chetan saw five new pens
8. Usha washed five small socks
9. Preeti took twelve small bags
10. Prema sings four old songs

° *List 13*

1. Preeti saw ten good dress
2. Priya bought one green hat
3. Prema wears some old socks
4. Raama bought many big balls
5. Sita saw twelve small toys
6. Krishna wears some old socks
7. Usha got some clean flowers
8. Rahul wants four red bags
9. Raja sings five old songs
10. Sita breaks three blue pens

° *List 14*

1. Rahul got one green hat
2. Raja saw some clean flowers
3. Priya got many big balls
4. Rahul saw many new balls
5. Rahul bought one green hat
6. Raja wants many big balls
7. Sita bought three blue pens
8. Preeti saw six old bags
9. Krishna keep twelve small bags
10. Chetan took ten good songs

° *List 15*

1. Preeti got one green hat
2. Preeti washed one clean dress
3. Prema wears five small socks
4. Raama took some clean flowers
5. Sita keeps one green hats
6. Krishna got many big balls
7. Usha keeps twelve small toys
8. Priya saw six old bags
9. Rahul sings four old songs
10. Raja washed many big bags

6. Usha bought four red toys
7. Usha got three blue pens
8. Usha took many green balls
9. Rahul washed ten blue bags
10. Chetan sings some old songs

° *List 46*

1. Preeti keeps ten good dress
2. Prema breaks three long toys
3. Raama saw some clean flowers
4. Raama got three blue pens
5. Sita saw one green hat
6. Sita got many big balls
7. Sita got five new books
8. Usha bought twelve small toys
9. Rahul keeps three blue bags
10. Chetan sings four old songs

° *List 49*

1. Preeti got ten good dress
2. Raja saw four red balls
3. Raama got some clean flowers
4. Sita bought one green hat
5. Krishna saw five new pens
6. Preeti keeps many big balls
7. Chetan washed some old socks
8. Usha saw many big toys
9. Rahul bought three blue bags
10. Usha sings five old songs

Continued..

◦ *List 16* 1. Rahul wears one clean dress 2. Raja took many big balls 3. Priya took one green hats 4. Raama got three blue pens 5. Sita got five new books 6. Krishna got four red toys 7. Chetan wants some clean flowers 8. Usha wears some old socks 9. Preeti wants three blue bags 10. Prema sings five old songs ◦ *List 18* 1. Preeti wears six old dress 2. Prema keeps many big balls 3. Raama washed five small socks 4. Sita got one green hat 5. Sita breaks ten old toys 6. Chetan wears some old socks 7. Krishna wants one green hat 8. Usha got three blue pens 9. Priya saw many big bags 10. Rahul sings four old songs ◦ *List 19* 1. Rahul washed five small socks 2. Raja washed one clean dress 3. Priya took twelve small toys 4. Raama wants five new books 5. Sita took one green hat 6. Krishna wants four red toys 7. Chetan got many big balls 8. Usha took some clean flowers 9. Preeti keeps twelve small bags 10. Prema sings many old songs ◦ *List 20* 1. Rahul saw one good dress 2. Raja bought some clean flowers 3. Priya wears some old socks 4. Raama saw one green hat 5. Sita keeps three blue pens 6. Krishna took twelve small toys 7. Chetan took many big balls 8. Usha saw three blue books 9. Preeti saw many big bags 10. Prema want six old songs ◦ *List 21* 1. Rahul bought ten good dress 2. Raja got some clean flowers 3. Priya wears five small socks 4. Raama bought one green hat 5. Sita breaks five red pens	

Continued..

6. Krishna wants twelve small toys 7. Chetan wants many big balls 8. Usha took ten good books 9. Preeti saw four red bag 10. Prema keeps six old songs ° *List 22* 1. Rahul got ten good dress 2. Preeti took ten good books 3. Raja wants some clean bags 4. Raama got one green hat 5. Sita got four red toys 6. Krishna breaks many big toys 7. Chetan keeps many big balls 8. Usha bought some clean flowers 9. Preeti saw some clean bags 10. Prema sings three old songs ° *List 24* 1. Rahul bought many big balls 2. Raja keeps three blue pens 3. Priya wants some clean flowers 4. Raama keeps one green hat 5. Sita saw four red balls 6. Krishna breaks ten old toys 7. Chetan breaks four old pens 8. Usha saw twelve small toys 9. Preeti bought many big bags 10. Prema sings ten old songs ° *List 25* 1. Rahul got many big balls 2. Raja breaks four old pens 3. Chetan saw twelve small toys 4. Raama took one green hat 5. Sita keeps some clean flowers 6. Krishna got twelve small toys 7. Chetan wears five small socks 8. Usha keeps three blue pens 9. Preeti bought four red bags 10. Prema took ten good songs ° *List 26* 1. Raja wants five new books 2. Priya wants one green hat 3. Raama saw four red balls 4. Sita wants four red toys 5. Chetan saw six old bags 6. Chetan breaks five red pens 7. Usha saw some clean flowers 8. Preeti bought three blue bags 9. Sita wants six old songs 10. Usha wants twelve small toys	

Continued..

◦ *List 27*

1. Raja wants three blue pens
2. Rahul keeps twelve small toys
3. Priya saw one green hat
4. Prema took three blue pens
5. Raama wants many big balls
6. Sita took some clean flowers
7. Krishna washed some old socks
8. Usha keeps four red toys
9. Chetan wants four red bags
10. Prema sings four old songs

◦ *List 28*

1. Preeti got some clean flowers
2. Preeti wears one clean dress
3. Rahul saw twelve small toys
4. Priya got one green hat
5. Prema took ten good books
6. Raama keeps many big balls
7. Krishna wears five small socks
8. Preeti bought five new bags
9. Prema washed some old bags
10. Prema sings six old songs

◦ *List 29*

1. Rahul keeps one green hat
2. Raja keeps many big balls
3. Priya breaks many big toys
4. Prema wants some clean flowers
5. Raama keeps five new books
6. Krishna breaks three blue pens
7. Preeti washed many big bags
8. Krishna bought twelve small toys
9. Rahul keeps four red bags
10. Usha took ten good songs

◦ *List 30*

1. Rahul bought four red toys
2. Raja got ,any big balls
3. Priya wants five new books
4. Prema took five new books
5. Raama wears five small socks
6. Krishna bought some clean flowers
7. Preeti washed some old bags
8. Chetan saw twelve small bags
9. Sita keeps six old songs
10. Usha wants five new songs

◦ *List 31*

1. Rahul wants twelve small toys
2. Raja took some clean flowers
3. Priya breaks three long toys
4. Prema keeps four red toys
5. Raama took three blue pens

6. Krishna wants many big balls 7. Usha sings ten good songs 8. Preeti washed three green bags 9. Chetan bought many big bags 10. Sita took six old songs ◦ *List 35* 1. Preeti wears six long dress 2. Raja wears five red socks 3. Raja took five new books 4. Prema saw some clean flowers 5. Sita breaks five big toys 6. Chetan wants some clean flowers 7. Usha keeps one green hat 8. Rahul saw four small bags 9. Usha got three blue pens 10. Sita sings six old songs ◦ *List 38* 1. Pretty got ten good dress 2. Raja washed five small socks 3. Prema took one clean hat 4. Raama bought three blue pens 5. Sita breaks three long toys 6. Chetan bought five new books 7. Chetan wants some clean flowers 8. Usha keeps many big balls 9. Preeti keeps six old bags 10. Sita sings three old songs ◦ *List 39* 1. Rahul wears one clean dress 2. Raja saw one green hat 3. Raja took many big balls 4. Prema saw some clean toys 5. Raama got three blue pens 6. Sita got five new books 7. Sita wants some clean flowers 8. Usha wants four red bags 9. Raja wants some clean flowers 10. Priya sings three old songs ◦ *List 41* 1. Raja got four red toys 2. Raja tool one green hat 3. Priya took ten good books 4. Prema keeps some clean flowers 5. Sita breaks three blue pens 6. Usha washed five small socks 7. Preeti keeps three blue bags 8. Priya sings some old songs 9. Usha wants many big balls 10. Chetan saw five new pens	

Continued..

Continued..

◦ *List 42*

1. Preeti washed six long dress
2. Raja saw twelve small toys
3. Priya washed five small socks
4. Prema breaks many big toys
5. Prema keeps five new books
6. Sita got some clean flowers
7. Sita took three blue pens
8. Usha bought one green hat
9. Preeti bought twelve small bags
10. Chetan sings ten old songs

◦ *List 43*

1. Preeti bought ten good dress
2. Priya wants many big balls
3. Preeti wants some clean flowers
4. Priya keeps six old bags
5. Raama washed some old bags
6. Sita bought twelve small toys
7. Sita wears some old socks
8. Usha got twelve small toys
9. Rahul bought four red bags
10. Chetan sings five old songs

◦ *List 44*

1. Preeti wears six long dress
2. Preeti took some clean flowers
3. Raja bought one green hat
4. Prema took many big balls
5. Sita got twelve small toys
6. Chetan wears some old socks
7. Usha got four red toys
8. Rahul washed some old bags
9. Chetan sings three old songs
10. Usha for three blue pens

◦ *List 47*

1. Preeti wears five small socks
2. Raja saw some clean flowers
3. Raja wants one green hat
4. Raama took ten big books
5. Sita bought four red toys
6. Prema keeps one green hat
7. Sita bought three blue pens
8. Krishna wears some old socks
9. Usha bought many big balls
10. Rahul washed twelve red bags

◦ *List 48*

1. Preeti wears one clean dress
2. Prema took ten good books
3. Raama wants some clean flowers
4. Raama keeps three blue pens
5. Sita saw many big toys
6. Krishna wears five small socks

Continued..

Continued..

7. Usha saw one green hat 8. Chetan saw many big bags 9. Rahul washed five small bags 10. Chetan sings many old songs ° *List 50* 1. Preeti got ten good dress 2. Rahul took ten good books 3. Raja wants four red toys 4. Raama saw five big pens 5. Sita bought some cleans flowers 6. Krishna saw one green hat 7. Raama washed some old socks 8. Usha saw four red balls 9. Rahul keeps twelve small bags 10. Usha keeps six old songs	

The above table classifies the 48 sentence lists of the Matrix Sentence Test in Indian-English into lists that can be interchangeably used in the presence of noise (equivalent) and lists that cannot be interchangeable used in the presence of noise (non-equivalent), for the determination of speech identification scores.

Appendix II:

Wilcoxon Signed Rank test statistics for the 11 lists

Comparison of list 2 with all other lists

List 2	z	*p*	List 2	z	*p*	List 2	Z	*p*
List 1	-4.01	.000	List 17	-4.47	.00	List 35	-3.18	.00
List 2	.00	1.000	List 18	-2.33	.02	List 36	-4.29	.00
List 3	-1.85	.064	List 19	-2.29	.02	List 37	-3.69	.00
List 4	-2.58	.010	List 20	-3.09	.00	List 38	-2.86	.00
List 5	-1.45	.154	List 21	-1.39	.16	List 39	-2.62	.01
List 6	-2.18	.029	List 22	-3.62	.00	List 40	-4.51	.00
List 7	-2.14	.032	List 24	-1.76	.08	List 41	-2.15	.03
List 8	-2.89	.004	List 25	-3.20	.00	List 42	-2.11	.03
List 9	-1.41	.158	List 26	-1.82	.07	List 43	-1.55	.12
List 10	-4.57	.000	List 27	-0.64	.52	List 44	-3.30	.00
List 11	-3.09	.002	List 28	-2.09	.04	List 45	-.65	.51
List 12	-1.31	.187	List 29	-1.65	.10	List 46	-4.12	.00
List 13	-3.04	.002	List 30	-1.45	.15	List 47	-1.44	.15
List 14	-3.61	.000	List 31	-1.74	.08	List 48	-3.14	.00
List 15	-3.66	.000	List 32	-4.24	.00	List 49	-4.34	.00
List 16	-3.08	.002	List 34	-0.50	.62	List 50	-2.21	.03

Comparison of list 10 with all other lists

List 10	Z	*p*	List 10	z	*p*	List 10	z	*p*
List 1	-.64	.52	List 17	-.70	.48	List 35	-.93	.35
List 2	-4.58	.00	List 18	-2.81	.01	List 36	-.15	.88
List 3	-3.85	.00	List 19	-2.03	.04	List 37	-.93	.35
List 4	-2.34	.012	List 20	-1.75	.08	List 38	-2.02	.04
List 5	-3.52	.00	List 21	-3.04	.00	List 39	-2.16	.03
List 6	-3.71	.00	List 22	-1.47	.14	List 40	-.36	.72
List 7	-2.58	.01	List 24	-2.65	.01	List 41	-2.24	.03
List 8	-1.58	.11	List 25	-.67	.50	List 42	-2.45	.01
List 9	-3.45	.00	List 26	-2.26	.02	List 43	-3.54	.00
List 10	.00	1.00	List 27	-3.65	.00	List 44	-1.72	.09
List 11	-1.64	.10	List 28	-2.53	.01	List 45	-3.73	.00
List 12	-3.10	.00	List 29	-3.12	.00	List 46	-.11	.91
List 13	-1.25	.21	List 30	-3.74	.00	List 47	-3.51	.00
List 14	-1.08	.28	List 31	-2.70	.01	List 48	-1.53	.13
List 15	-.87	.38	List 32	-.70	.48	List 49	-.11	.91
List 16	-2.10	.03	List 34	-4.50	.00	List 50	-2.79	.01

Comparison of list 17 with all other lists

List 17	Z	*p*	List 17	z	*p*	List 17	z	*p*
List 1	-.33	.74	List 17	.00	1.00	List 35	-.06	.96
List 2	-4.47	.00	List 18	-1.62	.11	List 36	-.99	.32
List 3	-2.91	.00	List 19	-2.13	.03	List 37	-.01	.99
List 4	-2.178	.03	List 20	-1.07	.28	List 38	-1.17	.24
List 5	-2.96	.00	List 21	-2.53	.01	List 39	-1.32	.19
List 6	-2.45	.01	List 22	-.42	.68	List 40	-.89	.37
List 7	-1.45	.15	List 24	-2.40	.02	List 41	-1.75	.08
List 8	-.57	.57	List 25	-.32	.75	List 42	-2.13	.03
List 9	-2.15	.03	List 26	-2.27	.02	List 43	-2.57	.01
List 10	-.70	.48	List 27	-3.26	.00	List 44	-1.31	.19
List 11	-.42	.68	List 28	-2.04	.04	List 45	-3.15	.00
List 12	-2.59	.01	List 29	-2.55	.01	List 46	-.42	.67
List 13	-.95	.34	List 30	-2.95	.00	List 47	-3.22	.00
List 14	-.16	.87	List 31	-2.61	.01	List 48	-1.05	.29
List 15	-.34	.73	List 32	-.04	.97	List 49	-.43	.67
List 16	-1.46	.14	List 34	-3.75	.00	List 50	-1.97	.05

Comparison of list 32 with all other lists

List 32	z	*p*	List 32	z	*p*	List 32	z	*p*
List 1	-.39	.70	List 17	-.04	.97	List 35	-.47	.64
List 2	-4.24	.00	List 18	-1.42	.16	List 36	-1.01	.31
List 3	-2.88	.00	List 19	-1.53	.13	List 37	-.07	.95
List 4	-1.76	.08	List 20	-1.66	.10	List 38	-2.04	.04
List 5	-3.21	.00	List 21	-2.53	.01	List 39	-1.80	.07
List 6	-2.81	.01	List 22	-.27	.79	List 40	-1.17	.24
List 7	-1.80	.07	List 24	-2.16	.03	List 41	-1.67	.09
List 8	-1.02	.31	List 25	-.34	.73	List 42	-2.06	.04
List 9	-2.80	.01	List 26	-2.22	.03	List 43	-2.81	.01
List 10	-.70	.48	List 27	-3.46	.00	List 44	-1.13	.26
List 11	-.55	.58	List 28	-2.07	.04	List 45	-3.86	.00
List 12	-2.36	.02	List 29	-2.84	.01	List 46	-.33	.74
List 13	-.70	.49	List 30	-3.47	.00	List 47	-3.24	.00
List 14	-.01	.99	List 31	-2.55	.01	List 48	-1.04	.30
List 15	-.40	.69	List 32	.00	1.00	List 49	-.48	.63
List 16	-1.64	.10	List 34	-4.54	.00	List 50	-2.32	.02

Comparison of list 34 with all other lists

List 34	z	*p*	List 34	z	*p*	List 34	z	*p*
List 1	-2.76	.01	List 17	-3.75	.00	List 35	-3.15	.00
List 2	-.50	.62	List 18	-2.48	.01	List 36	-4.59	.00
List 3	-1.55	.12	List 19	-2.17	.03	List 37	-4.80	.00
List 4	-2.07	.04	List 20	-2.67	.01	List 38	-3.48	.00
List 5	-1.26	.21	List 21	-.93	.35	List 39	-3.60	.00
List 6	-1.83	.07	List 22	-3.20	.00	List 40	-4.87	.00
List 7	-2.08	.04	List 24	-2.18	.03	List 41	-2.40	.02
List 8	-3.05	.00	List 25	-3.17	.00	List 42	-1.93	.05
List 9	-1.57	.12	List 26	-2.08	.04	List 43	-1.67	.09
List 10	-4.50	.00	List 27	-1.52	.13	List 44	-3.88	.00
List 11	-2.64	.01	List 28	-3.04	.00	List 45	-1.22	.22
List 12	-1.30	.19	List 29	-1.56	.12	List 46	-3.89	.00
List 13	-2.95	.00	List 30	-1.92	.06	List 47	-1.72	.08
List 14	-4.07	.00	List 31	-2.26	.02	List 48	-2.69	.01
List 15	-3.42	.00	List 32	-4.55	.00	List 49	-4.36	.00
List 16	-2.64	.01	List 34	.00	1.00	List 50	-2.49	.01

Comparison of list 36 with all other lists

List 36	z	*P*	List 36	z	*p*	List 36	z	*p*
List 1	-.96	.34	List 17	-.99	.32	List 35	-1.33	.18
List 2	-4.29	.00	List 18	-2.76	.01	List 36	.00	1.00
List 3	-3.86	.00	List 19	-2.47	.01	List 37	-1.07	.28
List 4	-2.43	.02	List 20	-2.24	.02	List 38	-2.69	.01
List 5	-3.42	.00	List 21	-3.45	.00	List 39	-2.52	.01
List 6	-3.57	.00	List 22	-1.60	.11	List 40	-.02	.98
List 7	-2.55	.01	List 24	-2.79	.01	List 41	-2.36	.02
List 8	-1.80	.07	List 25	-.92	.36	List 42	-2.43	.02
List 9	-3.46	.00	List 26	-2.95	.00	List 43	-3.59	.00
List 10	-.15	.88	List 27	-4.11	.00	List 44	-2.00	.04
List 11	-1.69	.09	List 28	-2.62	.01	List 45	-4.25	.00
List 12	-3.08	.00	List 29	-3.35	.00	List 46	-.49	.63
List 13	-1.83	.07	List 30	-4.04	.00	List 47	-3.56	.00
List 14	-.63	.53	List 31	-3.64	.00	List 48	-1.72	.09
List 15	-1.53	.13	List 32	-1.01	.31	List 49	-.63	.53
List 16	-2.86	.00	List 34	-4.59	.00	List 50	-3.26	.00

Comparison of list 37 with all other lists

List 37	z	*P*	List 37	z	*p*	List 37	z	*p*
List 1	-.12	.90	List 17	-.01	.99	List 35	-.19	.85
List 2	-3.69	.00	List 18	-1.73	.08	List 36	-1.07	.28
List 3	-2.50	.01	List 19	-1.80	.07	List 37	.00	1.00
List 4	-1.89	.06	List 20	-1.02	.31	List 38	-1.53	.13
List 5	-2.80	.01	List 21	-2.52	.01	List 39	-1.73	.08
List 6	-2.87	.00	List 22	-.73	.47	List 40	-1.11	.27
List 7	-1.91	.060	List 24	-2.55	.01	List 41	-1.83	.07
List 8	-.72	.47	List 25	-.10	.92	List 42	-1.64	.10
List 9	-2.73	.01	List 26	-1.67	.09	List 43	-3.01	.00
List 10	-.93	.35	List 27	-2.97	.00	List 44	-1.09	.28
List 11	-.66	.51	List 28	-2.00	.04	List 45	-3.78	.00
List 12	-2.54	.01	List 29	-2.46	.01	List 46	-.71	.48
List 13	-.69	.48	List 30	-2.90	.00	List 47	-2.81	.01
List 14	-.18	.85	List 31	-2.66	.01	List 48	-1.31	.19
List 15	-.64	.52	List 32	-.07	.95	List 49	-.68	.50
List 16	-1.47	.14	List 34	-4.80	.00	List 50	-1.89	.06

Comparison of list 40 with all other lists

List 40	z	*p*	List 40	z	*p*	List 40	z	*p*
List 1	-.93	.35	List 17	-.90	.37	List 35	-.96	.34
List 2	-4.51	.00	List 18	-2.48	.01	List 36	-.02	.98
List 3	-3.58	.00	List 19	-2.56	.01	List 37	-1.11	.27
List 4	-2.54	.01	List 20	-2.00	.05	List 38	-2.30	.02
List 5	-3.34	.00	List 21	-3.15	.00	List 39	-2.91	.00
List 6	-3.33	.00	List 22	-1.39	.16	List 40	.00	1.00
List 7	-2.48	.01	List 24	-2.91	.00	List 41	-2.47	.01
List 8	-1.73	.08	List 25	-.94	.35	List 42	-2.58	.01
List 9	-2.83	.01	List 26	-2.73	.01	List 43	-3.95	.00
List 10	-.36	.72	List 27	-3.89	.00	List 44	-2.24	.03
List 11	-1.44	.15	List 28	-2.80	.01	List 45	-4.52	.00
List 12	-3.17	.00	List 29	-3.18	.00	List 46	-.57	.57
List 13	-1.77	.08	List 30	-3.86	.00	List 47	-3.13	.00
List 14	-.91	.36	List 31	-2.98	.00	List 48	-1.78	.08
List 15	-1.35	.18	List 32	-1.17	.24	List 49	-.30	.76
List 16	-2.20	.03	List 34	-4.87	.00	List 50	-2.83	.01

Comparison of list 45 with all other lists

List 45	z	*p*	List 45	z	*p*	List 45	z	*p*
List 1	-2.64	.01	List 17	-3.15	.00	List 35	-3.11	.00
List 2	-.65	.52	List 18	-1.95	.06	List 36	-4.25	.00
List 3	-.80	.43	List 19	-1.44	.15	List 37	-3.78	.00
List 4	-1.25	.21	List 20	-2.05	.04	List 38	-2.73	.01
List 5	-.07	.95	List 21	-.36	.72	List 39	-2.13	.03
List 6	-.85	.39	List 22	-2.72	.01	List 40	-4.52	.00
List 7	-1.01	.31	List 24	-.88	.38	List 41	-1.69	.09
List 8	-2.08	.04	List 25	-2.25	.03	List 42	-1.01	.31
List 9	-.84	.40	List 26	-1.22	.23	List 43	-.87	.39
List 10	-3.73	.00	List 27	-.09	.93	List 44	-2.72	.01
List 11	-2.40	.02	List 28	-1.35	.18	List 45	.00	1.00
List 12	-.43	.67	List 29	-.61	.54	List 46	-3.30	.00
List 13	-2.14	.03	List 30	-.59	.55	List 47	-.50	.62
List 14	-2.97	.00	List 31	-.77	.44	List 48	-2.43	.02
List 15	-2.49	.01	List 32	-3.86	.00	List 49	-3.83	.00
List 16	-2.16	.03	List 34	-1.22	.22	List 50	-.89	.37

Comparison of list 46 with all other lists

List 46	z	*p*	List 46	z	*p*	List 46	z	*p*
List 1	-.58	.56	List 17	-.42	.67	List 35	-.55	.58
List 2	-4.12	.00	List 18	-1.99	.05	List 36	-.49	.63
List 3	-3.48	.00	List 19	-1.83	.07	List 37	-.71	.48
List 4	-2.35	.02	List 20	-1.38	.17	List 38	-1.33	.18
List 5	-3.25	.00	List 21	-2.89	.00	List 39	-1.73	.08
List 6	-2.79	.01	List 22	-1.22	.22	List 40	-.57	.57
List 7	-2.15	.03	List 24	-2.72	.01	List 41	-2.29	.02
List 8	-1.44	.15	List 25	-.54	.59	List 42	-2.82	.01
List 9	-2.67	.01	List 26	-2.32	.02	List 43	-3.38	.00
List 10	-.11	.91	List 27	-3.73	.00	List 44	-1.80	.07
List 11	-1.14	.25	List 28	-2.11	.03	List 45	-3.30	.00
List 12	-2.68	.01	List 29	-2.85	.01	List 46	.00	1.00
List 13	-1.23	.22	List 30	-3.46	.00	List 47	-3.59	.00
List 14	-.65	.52	List 31	-2.87	.00	List 48	-.89	.37
List 15	-.66	.51	List 32	-.33	.74	List 49	-.06	.96
List 16	-1.62	.11	List 34	-3.89	.00	List 50	-2.76	.01

Comparison of list 49 with all other lists

List 49	Z	*p*	List 49	z	*p*	List 49	z	*p*
List 1	-.87	.38	List 17	-.43	.67	List 35	-.37	.71
List 2	-4.34	.00	List 18	-2.10	.04	List 36	-.63	.53
List 3	-3.14	.00	List 19	-1.86	.06	List 37	-.68	.49
List 4	-2.47	.01	List 20	-1.87	.06	List 38	-1.38	.17
List 5	-3.82	.00	List 21	-3.09	.00	List 39	-2.13	.03
List 6	-3.14	.00	List 22	-1.23	.22	List 40	-.30	.76
List 7	-2.30	.02	List 24	-2.85	.00	List 41	-2.69	.01
List 8	-1.53	.13	List 25	-.55	.59	List 42	-2.58	.01
List 9	-2.79	.01	List 26	-2.27	.02	List 43	-3.05	.00
List 10	-.12	.91	List 27	-3.52	.00	List 44	-1.77	.08
List 11	-1.15	.25	List 28	-2.80	.01	List 45	-3.83	.00
List 12	-2.99	.00	List 29	-3.02	.00	List 46	-.06	.96
List 13	-1.25	.21	List 30	-3.93	.00	List 47	-3.52	.00
List 14	-.71	.48	List 31	-2.69	.01	List 48	-1.29	.20
List 15	-.85	.39	List 32	-.48	.63	List 49	.00	1.00
List 16	-2.00	.04	List 34	-4.36	.00	List 50	-2.71	.0