EFFECT OF NOISE ON THE SENTENCE IDENTIFICATION TEST IN KANNADA IN INDIVIDUALS WITH HEARING LOSS

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May, 2017

CERTIFICATE

This is to certify that this dissertation entitled **"Effect of Noise on The Sentence Identification Test in Kannada in Individuals with Hearing Loss"** is a bonafide work submitted in part fulfillment for degree of Master of Science (Audiology) of the student Registration Number: **15AUD024.** 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
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CERTIFICATE

This is to certify that this dissertation entitled **"Effect of Noise on The Sentence Identification Test in Kannada in Individuals with Hearing Loss"** has been prepared under my supervision and guidance. It is also being certified that this dissertation has not been submitted earlier to any other University for the award of any other Diploma or Degree.

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DECLARATION

This is to certify that this dissertation entitled **"Effect of Noise on The Sentence Identification Test in Kannada in Individuals with Hearing Loss"** is the result of my own study under the guidance of Dr. Geetha. C, Lecturer in Audiology, Department of Audiology, All India Institute of Speech and Hearing, Mysuru, and has not been submitted earlier to any other University for the award of any other Diploma or Degree.

Mysuru **Registration No.: 15AUD024**

May, 2017

This work is dedicated to my Dearest amma and appa

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Abstract

The present study intends to convert the Sentence identification test in Kannada language into an adaptive sentence in noise test which provides scores in terms of SNR at 50 % correct performance. The objectives of the present study were to compare the SNR-50 obtained using 25 lists of the sentence test material and across different degrees of hearing loss. The procedures included mixing of sentences in the 25 lists with a four-talker Kannada babble with each list having different SNR. After mixing, the sentences in babble stimuli were presented to 30 individuals with mild to moderately-severe hearing loss in the age range of 18 to 50 years to measure SNR-50. These individuals were further divided into Group I, Group II and Group III each containing 10 participants of mild, moderate and moderately-severe hearing loss. The results of list-wise comparison of SNR-50 revealed that though there were significant differences among a few lists, most lists were equivalent to each other. Group-wise comparison of SNR-50 revealed that the mild group differed statistically from both moderate and moderately severe hearing loss. However, there were no significant differences in SNR-50 obtained in groups with moderate and moderately-severe hearing loss. The sentence in noise test validated by the study can be conveniently used in clinical assessment of speech perception and in hearing aid research with multiple conditions without the risk of familiarisation and practice effect.

CHAPTER 1

INTRODUCTION

Individuals with hearing impairment suffer from a signal to noise ratio (SNR) loss in addition to elevated thresholds of hearing (Killion, Niquette, Gudmundsen, Revit & Banerjee, 2004). The SNR loss is defined as the increase in the signal to noise ratio required by a listener with hearing impairment to achieve 50% correct recognition performance of words, sentences or words in sentences (Killion, Niquette, Gudmundsen, Revit & Banerjee, 2004).

This SNR loss been reported to be due to the difficulties experienced by hearing impaired individuals in understanding speech in the presence of background noise with or without amplification (Grant & Walden, 2013). Hence, knowledge of SNR loss in an individual with hearing loss is vital for the hearing professional in predicting benefit with hearing aids in daily listening environments as well as to recommend appropriate technology to improve SNR in these environments (Killion et al., 2004). In a few individuals with lesser SNR losses appropriately fitted hearing aids alone suffice as a treatment option, while individuals with greater SNR losses may often require to be prescribed with assistive listening devices like hand held microphones, FM assistance etc., (Killion & Niquette, 2000).

The only way to quantify SNR loss in a person with hearing loss is to measure speech recognition through specifically designed speech in noise tests (Walden & Walden 2004; Rosen, Souza, Ekeland & Majeed, 2013). Two commonly used standard speech in noise tests are the Quick speech perception in noise test (QuickSIN) developed by Killion et al. (2004) and The Hearing in Noise test (HINT) described by Nilsson, Soli & Sullivan, (1994). HINT involves the use of sentences in continuous speech-spectrum shaped noise and an adaptive procedure to identify the

SNR required for 50% correct identification of whole sentences (SNR-50). On the other hand, QuickSIN uses sentences in the presence of four talker babble noise and identifies the SNR for 50 % correct identification of key words in sentences instead of whole sentences. Both the tests use sentence level speech material to produce SNR values thereby eliminating ceiling and floor effects which are prone to occur in percent scores (Nilsson, Soli, & Sullivan, 1994). They both provide information about suprathreshold hearing which is not obtained from an audiogram. Both the tests have been standardized and are widely being used in hearing and hearing devices related research studies (Wittkop, Albani, Hohmann, Peissig, Woods & Kollmeier, 1997). These also have been adopted in many languages (Sigfrid, 2008).

It is important to have such test materials in different languages because, an individual's performance in any speech perception task is affected by his/her mother tongue. Listeners have been found to have consistently better discrimination scores in their mother tongue than other languages (Delattre, 1964). Most importantly, the perception of non-native speech in adverse listening conditions such as in the presence of noise is twice as difficult as perceiving native speech (Lecumberri, Cooke & Cutler, 2010). In a country like India, there are multiple languages spoken across different regions. This necessitates the development of standardised speech perception in noise tests in Indian languages.

There are two standardized sentence tests in Kannada language. Avinash, Meti and Kumar (2010) have developed a QuickSIN test in Kannada language by constructing 12 lists with seven sentences from a pool of 60 sentences. The noise used was eight-talker speech babble that was mixed with the sentences at different SNRs. Thus in each list, the SNR varied from +20 dB SNR in the first sentence to -10 dB

SNR in the seventh sentence in 5 dB SNR steps. The results of their study revealed that seven out of twelve sentence lists were equivalent. In addition, mean identification scores at each SNR were plotted as a function of SNR and linear regression analysis was performed. With the help of the regression equation, SNR that resulted in 50% speech identification scores was found to be -6.17 dB in individuals with normal hearing sensitivity.

The sentence identification test in Kannada language containing a larger number of lists was developed and standardised by Geetha, Kumar, Manjula and Pavan (2014). The study used a normative design and included a development and a standardization phase. Sentences that were natural, low in predictability and equivalent in terms of difficulty were used to construct 30 lists of 10 sentences each and was standardized using 100 normal hearing participants. Standardization involved presenting the 30 lists to all participants at -5 dB SNR found to avoid a ceiling effect. The SNR of -5 dB was found to yield 50% correct performance in a pilot study of 15 native Kannada speakers. Normative scores of 100 normal hearing participants at -5 dB SNR was obtained. It was reported that there were 25 homogenous lists. Validation of this test has been done in individuals with different degrees of hearing impairment in quiet. The between group comparison revealed a significant difference between all constituent groups except the mild and the normal hearing groups. Within group comparison revealed no significant differences between the mean numbers of correctly identified words thus indicating equivalency of all 25 lists.

1.1. Need for the study

Everyday communication demands that listeners understand speech in varying degrees of noise. It has been proven that, under similar circumstances, listeners with sensorineural hearing loss (SNHL) have a greater degree of difficulty in understanding speech in noise than do listeners with normal hearing (Dubno, Dirks & Morgan, 1984). Speech identification tests in noise are important tools in the battery in the assessment of hearing and comparing performance of hearing devices and/or settings (Mueller, 2001). The review highlights the importance of having such test materials in different languages.

Though there are a few tests in Indian languages, they lack in some aspects. For example, the test developed by Avinash, Meti and Kumar (2010) has only seen equivalent lists and hence, not adequate for most hearing aid related research studies. Whereas, the sentences in Kannada language standardized by Geetha et al. (2014) have been devised to be tested at a single SNR (-5 dB) only and the test has been validated in individuals with hearing loss in quiet only. It is a known fact that, when presented under quiet conditions, speech intelligibility measures are inherently limited by ceiling effects.

Killion (1997) has evaluated individuals with hearing impairment with SIN test. It was reported that even the individuals with mild hearing loss required higher SNR than the normal individuals in the presence of noise, even when the testing is done at higher intensity levels. In addition, any test material should be sensitive to differences in speech identification abilities of individuals with hearing loss. This lends support to the idea of adopting the sentence identification test in Kannada language (Geetha et al, 2014) in an SNR format (by mixing the target sentences with multi talker babble) and validating the same in individuals with hearing impairment.

This would enable assessment of speech perception in clinical population in the most natural approximation of daily listening situations. The QuickSIN format will be adopted as it includes an ease of setup, administration and scoring, similarity between normative and sample values and the ability to provide an estimate of SNR loss with reference to normal performance (Killion, 1997).

1.2. **Aim of the study**

The present study aimed to validate the sentence identification test in Kannada language in SNR-50 format across lists in individuals with different degrees of hearing impairment in the presence of background noise.

1.3. **Objectives of the study**

The objectives of the present study were-

1. To mix sentences with speech babble at different SNRs within each list for obtaining SNR-50,
2. To estimate SNR at which 50% correct responses could be obtained using the sentence identification test in Kannada,
3. To compare SNR-50 across different sentence lists, and
4. To compare SNR -50 across different degrees of sensorineural hearing loss.

CHAPTER 2

REVIEW OF LITERATURE

Speech perception is vital to the communication process and hence its assessment in the audiometric testing is indispensable for successful audiologic rehabilitation (Mueller, 2001; Wilson & McArdle, 2005). Tests of speech perception employ a variety of stimuli like non-sense syllables, monosyllabic words, bisyllabic words and sentences (Tyler, 1994). Each of these have been studied for their advantages and disadvantages over each other (Hirsh, 1952; Cahart, 1965; Tyler, 1994). For instance, speech perception testing using non-sense syllables may enable a direct and straight forward examination of speech features that are perceived. However, such a test may lack face validity and context effects that occur in natural representative environments. Similarly, a word or a syllable level material can be used to test an individuals' recognition ability, however, co-articulatory influences and rapid changing nature of natural speech stimulus are not accounted for (Hirsh, 1952; Tyler, 1994).

One of the most common applications of word level materials for speech perception testing is the use of monosyllabic words during hearing aid selection and fitting process. The objective of this testing is to compare the unaided and aided speech perception and to demonstrate one hearing aid's superior performance over another to the hearing aid users. However, this test gives very limited insight regarding the individual's speech recognition performance in real world conditions (Mueller, 2001; Taylor, 2003). Hence, sentence material is used in the current study and the subsequent review highlights the importance of sentence length materials in speech in noise tests. The review is presented under the following headings:

2.1. Speech perception tests using sentences

2.2. Sentence test materials in foreign languages

2.3. Sentence test materials in Indian languages

2.1. Speech perception tests using sentences

Sentences can be used to assess both recognition and comprehension in a natural and a time saving paradigm. The advantages of sentence level materials are as follows: (i) they can provide insight regarding an individual's performance in more realistic communication scenarios; (ii) they are considered to be valid indicators of intelligibility and give better representation of verbal communication (Tyler,1994); (iii) they provide better accuracy and effectiveness in measuring speech reception thresholds (due to steeper intelligibility functions of sentence level materials in comparison to testing using single words (Kollmeier & Wesselkamp, 1997); (iv) they contain contextual cues and are expected to have better predictive validity compared to words; (v) they assesses co-articulation as well as temporal aspects of speech; and (vi) they have face validity as 'natural' and 'meaningful' stimuli for assessing auditory function (Miller, Heise & Lichten , 1951).

Over the years several sentence level test materials have been developed. Some of these are used in the context of assessment of central auditory processing disorders like the competing sentences test (Willeford, 1968), the dichotic sentence identification test (Fifer et al, 1983) and the synthetic sentence identification test (Speaks & Jerger, 1965) while others are used to test speech recognition or identification performance in the hearing impaired population. The following review focuses on materials of the latter category i.e. sentence level speech perception materials used to assess speech perception in individuals with hearing loss.

One of such test used to assess speech perception the PAL auditory test No.12 (Hudgins, Hawkins, Karlin & Stevens, 1947). This test measures speech recognition threshold using 8 lists with 28 short sentences. Similarly, speech reception threshold (SRT) testing using sentence stimuli (Plomp, 1986) is another test consisting of 10 lists of 13 sentences with equal intelligibility in noise. This test was found to reliably estimate SRT using an open set task. These sentences were divided into seven groups of 8 sentences with each group presented at a level 4 dB lower than the previous group for the purpose of SRT measurement.

Besides the materials of speech recognition mentioned above, there are materials developed to specifically test speech identification performance. One of the first sentence tests of this kind was the Central Institute of Deaf (CID) everyday sentences test in English developed by Silverman and Hirsh in 1955. The CID test consists of 10 sets of 10 sentences with 50 keywords uses a target-word format, i.e., although the participant must repeat the entire sentence during testing, scoring is based on correct recognition of key words. The PAL Auditory Test No. 8 (Hudgins, Hawkins, Karlin & Stevens, 1947) uses 100 sentences and a one word response multiple choice response paradigm for scoring. The Danhauer Beck Sentence test (Danhauer, Beck, Lucks & Ghadialy, 1988) is one other test of sentence identification comprising ten sentences and ten questions with a total of 140 syllables that can be administered in audio or visual or audio visual modes. The English High Predictable-Low Predictable Sentence test for Non-Native English speakers (EHLPS) is another English test for Indian English speakers developed by Rahana and Yathiraj in 2007. This test was found to be useful in the clinical assessment of the perceptual problems in individuals having hearing loss.

In addition to using valid and meaning stimuli like sentences, it is also equally important for audiologists to simulate typical listening situations during the assessment of speech perception ability of an individual. Tyler (1994) added the fact that listeners with sensorineural hearing loss (SNHL) experience greater difficulty in understanding speech in noise than normal hearing listeners (Niemeyer, 1965; Cooper & Cutts, 1971; Keith & Talis, 1972; Kuzniarz, 1973; Cohen & Keith, 1976; Leshowitz, 1977). Thus, audiologists should not restrict themselves to testing in quiet or speech shaped noise. Despite the ease of stimulus control and repeatability being the key benefits of using these materials it is important to understand that these measures are either inherently limited by ceiling effects or may not be representative of everyday listening environments stated the dynamic nature of interfering noise (Tyler,1994).

Studies have also revealed that speech perception measures in quiet have failed to reliably predict speech perception ability of listeners in noisy environments.(Killion & Christensen, 1998; Killion & Niquette, 2000; Killion, 2002; Walden & Walden, 2004).This prediction is difficult to make because of the distortion component of hearing loss (Plomp, 1978) and hence, it must be measured directly (Killion, 2002). Incorporating background noise into standardized speech tests has been reported to improve both the sensitivity and validity of word-recognition measures (Findlay, 1976; Beattie, 1989; Willott, 1991; Sperry et al., 1997).

Multi-talker babble is preferable as a competing stimuli primarily because it is the most common environmental noise encountered by listeners in everyday life (Plomp, 1978). Secondly, multi-talker babble creates a difficult listening environment because of the speech shaped spectrum with minimal amplitude modulation of the envelope and aperiodicity.

In the past studies have also shown that speech recognition performance in multi-talker babble also succeeds in establishing a clear separation between individuals with normal hearing and individuals with hearing loss (Findlay, 1976; Dubno et al, 1984, Beattie, 1989; Wilson & Strouse, 2002; Wilson, 2003) than speech shaped noise. On average, individuals with hearing loss have required the signal to be 10–12 dB higher than the multitalker babble to obtain a performance level of 50% correct, whereas individuals with normal hearing reach 50% correct at signal-to-babble ratios (S/B) of 2–6 dB (Mcardle, Wilson & Burks, 2005). Multi-talker babble involves several speakers talking simultaneously with none of the conservations intelligible.

2.2. Sentence test materials in foreign languages

Speech recognition in noise tests are important in audiometric test battery as they provide valuable clinical information regarding the listeners' ability to perceive speech in representative realistic environments; helps in better decision making about hearing aid selection; and also in predicting success with these devices (Bray & Nilsson, 2002). In addition, it has been shown that the SNR loss in a person cannot be predicted from a pure-tone audiogram (Walden & Walden, 2004). These tests fall into two broad categories namely Fixed signal-to-noise ratio (SNR) tests that measure percent correct at a fixed SNR and the adaptive SNR tests that measure the speech to noise ratio as the intensity level of either the noise or the speech is varied. However easy it may be to obtain a simple percent score using fixed SNR tests, it's difficult to determine the optimal SNR for testing to appropriately predict outcomes in real life scenarios. Furthermore adaptive tests can be conveniently performed under earphones while fixed SNR tests are to be carried out in sound field (Taylor, 2003). The Connected Speech Test (CST) developed by Cox, Alexander and Gilmore (1987) and the Speech Perception in Noise test (SPIN) provided by Kalikow, Stevens and Elliot (1977) are fixed SNR tests while Hearing in Noise Test (HINT) and the Quick Speech In Noise (QuickSIN) are some of the adaptive SNR tests.

The Speech Perception in Noise test (SPIN) is a test of everyday speech reception involving presentation of sentences in babble where the listener’s task is to repeat the last word of the sentence which is always a monosyllabic noun (keyword). Sentences in the test are of two types: High predictability sentences in which the last keyword is somewhat predictable from the context and low predictability sentences in which the final keyword is not predictable from the context. This test is considered to compare listener’s ability to perceive linguistic-contextual cues with the ability to perceive acoustic phonetic speech cues as provided through high predictability sentences and low predictability sentences respectively. These high predictability (PH) and low predictability (PL) sentences have been formulated into 10 forms with 25 PH items interleaved with 25 PL items in a random fashion in each form (a total of 50 sentences per form).

The Connected Speech Test (CST) contains 48 passages of connected conversational speech with 25 keywords in every passage for scoring. These key words were selected based on the potential difficulty or intelligibility across six signal to babble ratio conditions viz. -3, -4, -5, -6, -7, -8 dB when mixed with a six talker babble. Percent correct scores for each potential keyword selected prior to testing revealed five levels of intelligibility. The objective of assessing intelligibility in this fashion was to incorporate five scoring words from each of the five intelligibility categories thus a total of 25 keywords per passage. The authors also reported that all 48 passages were equivalent in terms of intelligibility. Thereby any four randomly selected passages out of the total passages can be used to obtain an average intelligibility score while testing individuals. This produced 12 equivalent CST forms for clinical SNR testing. The CST passages were validated on a second group of normal hearing individuals and it was reported that the 95% critical difference for mean scores across any four randomly chosen passages was 14 rationalized arcsine units (Cox, Alexander & Gilmore, 1987)

The QuickSIN test is a short and improvised version of Speech in Noise (SIN) test (Killion & Villchur, 1993) and its subsequent Revised Speech in Noise (RSIN) test (Cox, Gray, & Alexander, 2001). The SIN test developed by Killion and Villchur in 1993 had 360 sentences divided as 9 blocks of 40 sentences each. Each block was further divided as 2 sections with one being presented at 70 dBHL and the other at 40 dBHL to represent loud and soft speech in realistic environments respectively. Each of these two sections contained 20 sentences to be presented as five sentences at each of the four signal to noise ratios viz. 15, 10, 5, and 0 db. Each of these sentences had 5 keywords and hence a total of 25 keywords at each SNR. Scoring involved obtaining the total number of keywords repeated correctly at each SNR, multiplying it by 4 to obtain a percent correct score, plotting these scores against the SNRs on a graph and interpolating SNR that yields 50% correct performance. However the test had a number of limitations such as being time consuming, as employing a difficult graphical scoring, a lack of equivalence between blocks (Killion et al.,1996; Bentler, 2000) and occurrence of ceiling and floor effects (Bentler,2000).

To overcome the above mentioned limitations, Killion et al (2004) provided a short and improvised version of the SIN test named the Quick speech perception in noise test (QuickSIN). This test consists of 12 equivalent lists of six sentences one presented at each SNR 25, 20, 15, 10, 5 and 0 dB SNR. Another standard speech in noise test given by Nilsson, Soli & Sullivan, (1994) is the Hearing in Noise test (HINT).The HINT involves the use of 25 phonemically balanced lists of 10 sentences each presented in spectrally matched noise to obtain sentences sSRTs adaptively. The HINT and QuickSIN constitute two commonly used standard clinical speech recognition tests.

The HINT developed by Nilsson, Soli and Sullivan (1994) involves the use of sentences in continuous speech-spectrum shaped noise and an adaptive procedure to identify the SNR required for 50% correct identification of whole sentences (SNR-50). On the other hand, QuickSIN uses sentences in the presence of four talker babble noise and identifies the SNR for 50 % correct identification of key words in sentences instead of whole sentences. Both the tests use sentence level speech material to produce SNR values thereby eliminating ceiling and floor effects which are prone to occur in percent scores (Nilsson, Soli, & Sullivan, 1994). They both provide information about supra-threshold hearing which is not obtained from an audiogram. Both the tests have been standardized and are widely being used in hearing and hearing devices related research studies (Wittkop et al., 1997). These also have been adopted in many languages. The HINT test is available in at least 15 languages including American English, Brazilian Portuguese, Bulgarian, Turkish, Castilian, Spanish, Latin American Spanish, French, Korean, Norwegian, Malay, Japanese, Canadian French, Cantonese, Taiwanese and Mainland Mandarin (Sigfrid, 2008).

Apart from English, these materials have been developed in several other native languages. Kollmeier and Wesselkamp (1997) developed the German sentence identification test consisting of 20 test lists with 10 phonemically balanced sentences. Performance –intensity discrimination functions were obtained for these final 20 lists which revealed that 50% sentences scores could be obtained at a SNR of –6.1 dB. Similarly Plomp and Mimpen (1979) developed a sentence test for the Dutch language by constructing 10 lists of 13 phonemically balanced sentences each in the background of speech shaped noise with a long term spectrum similar to the sentences and the SRT obtained using the material averaged across ten listeners was reported separately for left and right ear as - 5.6dB and - 6.2dB SNR respectively.

It is important to have such test materials in different languages because, an individual's performance in any speech perception task is affected by his / her mother tongue. Studies of speech perception in noise have repeatedly shown that perception of non-native speech in adverse listening conditions such as in the presence of noise is twice as difficult as perceiving native speech (Lecumberri, Cooke & Cutler, 2010). As a fact it has also been shown that even true bilingual listeners are never as competent as monolinguals in the presence of noise (Mayo, Florentine & Buus, 1997; Rogers, Lister, Febo, Besing & Abrams, 2006). In a country like India, there are multiple languages spoken across different regions. This necessitates the development of standardised speech perception in noise tests in Indian languages.

2.3 Speech in noise tests using sentences in Indian languages

A Hindi sentence test for measuring speech recognition in noise has been developed by Jain, Narne, Singh, Kumar and Mekhala (2014) which contains twenty lists of 10 sentences each found to be equivalent in terms of intelligibility. The SNR at

50% correct sentence identification was estimated to be – 4.65 dB with an S.D of 0.45 on 30 naïve Hindi speakers.

Similarly, a Telugu sentence test was developed by Tanniru, Narne, Jain, Konadath, Singh, Sreenivas and Anusha (2017) by constructing 20 lists, each consisting of 10 equally intelligible sentences. Of these, 15 lists were found to be comparable in terms of difficultly and hence were included in the final test material. It has also been reported that the mean SRT in noise across the lists corresponded to -2.74 with a standard deviation of 0.21.

There are two standardized sentence tests in Kannada language. Avinash, Meti and Kumar, (2010) have developed a QuickSIN test in Kannada language by constructing 12 lists with seven sentences each from a pool of 60 sentences. QuickSIN was adopted as a test format over HINT mainly due to its clinical advantages. These included an ease of setup, administration and scoring and similarity between normative and sample values. In addition, the results of QuickSIN are provided as SNR Loss scores relative to normal performance. That is, the QuickSIN score represents the SNR a listener with hearing loss requires above the SNR a normal hearing listener requires to achieve 50% correct sentence identification (SNR-50) (Killion, 1997b). The HINT score does not include reference to normal performance. The noise used was eight-talker speech babble that was mixed with the sentences at different SNRs. Thus in each list, the SNR varied from +20 dB SNR in the first sentence to -10 dB SNR in the seventh sentence in 5 dB SNR steps.

The results of their study revealed that seven out of twelve sentence lists were equivalent. In addition, mean identification scores at each SNR were plotted as a function of SNR and linear regression analysis was performed. With the help of the regression equation, SNR that resulted in 50% speech identification scores was found to be -6.17 dB in individuals with normal hearing sensitivity.

The sentence identification test in Kannada language containing a larger number of lists was developed and standardised by Geetha, Kumar, Manjula and Pavan (2014). This material was developed to predominantly cater to the needs of the local population that seeked clinical services. The study used a normative design and included a development and a standardization phase. Sentences that were natural, low in predictability and equivalent in terms of difficulty was used to construct 30 lists of 10 sentences each and was standardized using 100 normal hearing participants. Standardization involved presenting the 30 lists to all participants at -5 dB SNR found to avoid a ceiling effect. The SNR of -5 dB was found to yield 50% correct performance in a pilot study of 15 native Kannada speakers. Normative scores of 100 normal hearing participants at -5 dB SNR was obtained.

It was reported that there were 25 homogenous lists. Validation of this test has been done in individuals with different degrees of hearing impairment viz mild, moderate, moderately-severe and severe hearing loss in quiet. The between-group comparison revealed a significant difference between all constituent groups except the mild and the normal hearing groups. Within group comparison revealed no significant differences between the mean numbers of correctly identified words thus indicating equivalency of all 25 lists. The Kannada Sentence Identification test was thus proved to be an efficient speech intelligibility measure and a potential speech in noise measure.

After reviewing the literature, it can be inferred that the use of sentence length speech material and adaptive procedures that yield an SNR score are the most natural, relevant and valid tools for assessing speech perception in noise.(Nilsson, Sullivan, & Soli, 1990; Nilsson, Soli, & Sullivan, 1994; Killion & Niquette, 2000).This is because fixed SNR tests that provide percent correct score at some pre-decided SNR are prone to floor and ceiling effects and they fail to provide insight into the SNR loss or the SNR needs in everyday listening environments.

The current study thus aimed to convert the sentence identification test that is administered in quiet or at a fixed global SNR (-5dB) to an adaptive SNR test with multiple premixed SNRs. Specifically the study assessed the effect of noise i.e. four talker babble in Kannada language on the sentence identification test in Kannada language in individuals with hearing impairment by obtaining SNR-50 using the same and comparing it across 25 homogenous lists of the test. The four-talker babble was chosen as a competing stimuli as it provided an efficient simulation of realistic social gathering. This was concluded based on a study which showed that greatest changes in recognition performance occurred when the number of talkers increased up to 4, with little changes after that (Rosen, Souza, Ekeland & Majeed, 2013). Kannada speech babble was preferred as competing stimuli because native language speech babbles have been reported to yield poorer sentence recognition scores when compared to their foreign language counterparts (Engen & Bradlow, 2007).

CHAPTER 3

METHODS

The current study aimed to convert the Kannada sentence identification test developed by Geetha et al., 2014 into SNR-50 format and investigate the list equivalency across different degrees of hearing loss. The study also aimed to compare SNR-50 across three degrees of sensorineural hearing loss namely mild, moderate and moderately-severe hearing loss. A standard group comparison design was used for the same. The methods included three steps. Step 1 included conducting a pilot study to identify the range of SNRs that yielded minimum and maximum speech recognition scores respectively. Step 2 involved mixing the sentences in the 'Sentence identification test in Kannada language' with four talker Kannada babble to yield SNR ranges obtained in the pilot study. Step 3 involved obtaining SNR-50 in individuals with mild, moderate and moderately severe hearing loss using the sentence- babble stimuli prepared in step 2.

3.1. Participants

Thirty listeners in the age range of 18 to 50 years (mean age = 37.73, SD = 10.77; males = 18 and females = 12) with mild to moderately-severe flat sensorineural hearing loss in the test ear were selected. This group was further subdivided based on the degree of hearing impairment as Group I, Group II and Group III containing 10 participants each with mild, moderate and moderately-severe hearing loss respectively. All participants underwent a routine audiological assessment inclusive of pure-tone audiometry and immittance assessment to estimate the degree of hearing loss and to rule out any conductive pathology. An informed consent was obtained prior to testing from all participants. Following are the inclusion and exclusion criteria that were used to select participants.

Inclusion criteria.

- All participants had normal middle ear functioning as evidenced by an 'A' or 'As' tympanogram and presence or absence of acoustic reflexes correlating with the degree of hearing loss
- The speech identification scores (SIS) were appropriate to the degree of hearing loss
- All participants had completed at least 10^{th} standard, and
- All participants were native speakers of Kannada language.

Exclusion criteria.

- History or presence of any middle ear or neurological as well as speech and language problems identified using audiological or non-audiological investigations, and
- Presence of any other associated problems identified through a detailed case history

3.2. Instrumentation

- A calibrated diagnostic audiometer was used for pure-tone audiometry. Air conduction and bone conduction thresholds were obtained using a TDH- 39 supra aural headphones and a Radio ear B- 71 bone vibrator, respectively.

- Tympanometry and Reflexometry were performed using a calibrated middle ear analyser, GSI Tympstar.

- A personal computer with an Intel Core i5 processor with windows 8 configuration connected to the auxiliary input of a GSI-61 audiometer was used to present the speech in noise stimuli through calibrated Sennheiser HDA 200 closed dynamic headphones.

- AUX Viewer was used to mix target sentences and speech babble to yield 10 different SNRs viz. -7, - 4, -1, 2, 5, 8, 11, 14, 17 and 20 dB SNR.

3.3. Stimuli

- Phonemically balanced (PB) word list developed by Yathiraj and Vijayalakshmi (2005) was used to obtain SIS scores during routine hearing evaluation.

- Speech in noise stimuli was obtained by mixing recorded sentences from Kannada sentence identification test developed by Geetha et al. (2014) with four talker babble generated by Nayana, Keerthi and Geetha (2016) was used. The sentence identification test developed by Geetha et al. (2014) has 25 equivalent list with ten sentences in each list.

3.4. Step 1: Pilot study

A pilot study was conducted on 5 adult listeners (age range = 18 - 50 years) with mild to moderately-severe sensorineural hearing loss (one individual with mild, two individuals with moderate and two individuals with moderately-severe hearing impairment) to identify SNRs that yielded maximum speech recognition scores and minimum speech recognition scores respectively, and thus arrive at a suitable range of SNRs and step size for identifying SNR-50 in individuals with hearing loss. Based on the performance of these individuals, the lowest SNR was chosen to be -7dB SNR and the highest being +20 dB SNR.

3.5. Step 2: Stimulus preparation

Each of the 10 sentences in 25 equivalent lists (a total of 250 sentences) of the sentence identification test in Kannada language (Geetha et al., 2014) were mixed with the four talker babble to yield different SNRs. The mixing was done such that ten sentences in each list were mixed with ten different SNRs viz. -7, - 4, -1, 2, 5, 8, 11, 14, 17, 20 dB SNR with the first sentence having 20 dB SNR and the last sentence having -7dB SNR. The range of SNRs were chosen based on the pilot study. Four talker babble was chosen as a competing noise based on the results of a study which showed greatest changes in recognition performance as the number of talkers increased up to four talkers and lesser changes after that (Rosen, Souza, Ekeland & Majeed, 2013). AUX Viewer was used to generate the sentence in noise stimuli by suitably altering the RMS of the babble with reference to the constant RMS of target sentences to yield specific SNRs. Testing was carried out in sound treated rooms with ambient noise levels within permissible limits (ANSI S3.1, 1991).

3.5. Step 3: Procedure for obtaining SNR-50

The test involved presenting 25 lists of sentences (with 10 sentences each) in noise stimuli decreasing from +20 dB SNR to -7 dB SNR in steps of 3 dB SNR. The sentences were presented in a random order and none of the sentences were repeated to avoid familiarity effects. The listeners were instructed to repeat as many words as possible from sentences presented at a level comfortable to them by progressively decreasing SNRs from +20 dB to -7 dB SNR. The sentences in babble were routed from a personal computer to a calibrated GSI-61 audiometer to the listener through a Sennheiser closed dynamic headphone at their most comfortable level. Prior to the actual testing, practice sentences (sentences not included in the 25 lists) were presented. Scoring of individual sentences was based on the number of key words identified. At each of the 10 SNRs, sentences were scored based on the number of key words correctly repeated, where contractions, spelled out contractions, identifiable mispronounced words, and changes in plurality were considered correct. The maximum number of key words possible for each sentence was four. A score of 1 was given to each correctly identified key word. Incorrect and partially correct key words were given a score of 0. Sentence wise scores were tabulated for each of the twenty five lists.

Spearman-Karber equation given by Finney (1952) was used to obtain SNR-50 for each of the 25 lists. The equation is as follows:

SNR-50= i + ½(d) – (d) (# correct) / (w)

Where,

I = the initial presentation level (dB S/B)

d = the attenuation step size (decrement)

w = the number of key words per decrement

Correct = total number of correct key words

Thus, for each participant, the SNR at 50% performance obtained using the above mentioned formula was obtained for all 25 lists. Test retest reliability check was performed on 10% of the participants where SNR-50 was measured twice with an interval of at least two weeks.

Statistical analysis

The SNR-50 values obtained by all the 30 listeners were subjected to statistical analysis using the SPSS (Statistical package for social science) software version 20. Friedman test was used to identify significant differences in SNR-50 scores between the 25 lists. Further, Wilcoxon Signed Rank Test was used for pair-wise comparison of SNR-50 across lists within each group. Krushkal-Wallis test and Mann-Whitney U test were used respectively to analyze differences in SNR-50 between three groups, if any.

CHAPTER 4

RESULTS

The aim of the present study was to compare SNR-50 obtained across the 25 lists of the Kannada sentence Identification test in the presence of 4-talker babble in individuals with different degrees of hearing sensorineural hearing loss. These individuals were divided into three groups. Group I consisted of participants with mild hearing loss, Group II of participants with moderate hearing loss and Group III comprised of individuals with moderately-severe hearing loss.

The data was statistically analyzed for normality using the Shapiro-Wilk's test. The results of the normality test revealed a normal distribution ($p < 0.05$) of SNR-50 values across different groups with different degrees of hearing loss for 25 lists. However, the standard deviation was observed to be very high and hence, non-parametric tests were used to compare SNR-50 scores across different groups with different degrees of hearing loss for 25 sentence lists.

4.1. Comparison of SNR-50 across different lists

The mean, median and standard deviation (SD) of SNR-50 for all the 25 lists are given in the Table 4.1. A lesser SNR-50 value indicates better performance and a larger SNR-50 indicates poorer performance.

Table 4.1

Mean, median and SD of SNR-50 for all the 25 sentence lists (N = 30; n =10 in each group).

Lists	Group I			Group II			Group III		
	Mean	**Median**	**SD**	**Mean**	**Median**	**SD**	**Mean**	**Median**	**SD**
List 1	1.82	1.25	5.72	7.10	8.00	4.12	6.05	6.12	2.57
List 2	0.35	-0.62	3.94	6.57	6.87	4.39	5.45	6.12	2.65
List 3	-0.17	-0.25	4.36	5.75	6.50	4.16	4.62	4.25	2.65
List 4	0.27	0.12	3.50	3.87	4.62	3.59	3.80	4.62	2.74
List 5	0.65	-0.25	3.83	5.82	6.87	4.35	4.25	3.50	2.97
List 6	-0.40	-1.37	4.70	2.90	2.75	3.56	4.17	5.00	3.69
List 7	-0.25	-1.00	3.64	4.75	4.25	3.40	4.85	3.87	2.66
List 8	-0.32	-0.62	4.47	4.70	4.62	4.70	4.70	6.12	2.69
List 9	-0.70	-0.25	4.17	3.57	3.50	4.62	4.70	3.87	2.76
List 10	-1.15	-2.12	4.01	5.07	5.00	3.52	4.32	5.00	3.21
List 11	-0.25	-0.25	4.24	5.22	3.87	3.46	5.82	6.87	2.92
List 12	-0.70	-0.25	3.79	4.92	4.62	3.91	5.22	6.12	3.04
List 13	-0.40	-1.00	4.62	4.40	4.62	3.90	4.10	4.62	3.60
List 14	-0.25	0.12	5.04	4.25	4.25	3.00	3.42	3.12	2.13
List 15	-1.22	-1.75	3.90	4.55	4.62	3.48	3.72	4.62	3.20
List 16	-0.62	-0.62	3.90	4.02	3.50	3.31	3.72	3.87	3.20
List 17	-1.75	-3.25	5.80	3.12	3.12	4.36	2.87	3.50	2.77
List 18	-1.37	-1.75	4.15	3.05	3.12	3.74	4.32	4.25	2.79
List 19	-1.22	-1.75	3.22	4.77	4.25	4.21	3.95	4.25	3.52
List 21	-1.15	-0.62	4.07	3.50	3.12	3.60	3.27	2.75	2.82
List 22	-0.85	-1.37	3.92	4.55	2.75	3.57	3.35	2.75	3.31
List 23	-1.52	-1.00	4.56	3.87	3.87	3.02	3.57	3.50	2.38
List 24	-1.15	-2.12	4.35	4.70	4.25	3.26	3.42	3.87	2.79
List 25	-1.22	-2.12	3.90	4.40	3.50	3.67	2.90	3.12	2.39

It can be observed from Table 4.1 that the mean SNR-50 ranged from - 1.75 to 1.82 dB SNR in Group I, from 2.90 to 7.1dB SNR in Group II, from 2.87 to 6.05dB SNR in Group III. Friedman test was performed to see if there was a statistically significant difference in SNR-50 scores between lists within each group. The results of Friedman test revealed that there was a significant difference between lists in the Group I ($\chi^2 = 45.15$; $p < 0.01$), in Group II ($\chi2 = 70.12$; $p < 0.001$) and in group III

($\chi2 = 57.16$; $p < 0.001$) Hence, pair-wise comparisons of 25 lists were performed for each group separately using Wilcoxon signed-rank test.

Table 4.2
Comparison of SNR-50 across 25 sentences lists using Wilcoxon Signed-rank test in Group I

Lists (A)	**Lists that are statistically different from A**
L1	L3(-2.11*), L6(-2.25*), L7(-2.03*), L8(-2.67**), L9(-2.19*), L10(-2.49*), L11(-2.37*), L12(-2.36*), L14(-2.37*), L15(-2.50*), L16(-2.52*), L17(-2.80**), L18(-2.71**), L19(-2.19*), L20(-2.52*), L21(-2.44*), L22(-2.49*), L23(-2.82**), L24(-2.60**), L25(-2.70**)
L2	L18(-2.25*), L19(-1.97*), L20(-2.09*), L22(-1.99*), L23(-2.14*), L25(-2.31*)
L4	L18(-2.32*), L22(-2.32*)
L5	L10(-2.11*), L12(-1.97*), L15(-2.45*), L16(-2.15*), L17(-2.07*), L18(-2.51*), L19(-2.55*), L20(-2.54*), L22(-2.31*), L23(-2.53*), L24(-2.36*), L25(-2.83**)

L8	L23(-2.26*)
L11	L20(-2.32*)
L14	L23(-2.53*)

Note: Only the significant differences are given in the table; L denotes lists; the numeric denotes the number of list. Z value for each comparison is given within parentheses next to the corresponding list. denotes p< 0.05; ** denotes p <0.01.*

It can be observed from the Table 4.2 that most of the lists did not have statistically significant differences in SNR-50 scores from other lists in Group I. A few lists like Lists 1, 2 and 5 were found to be significantly different from many other lists. List 1 was significantly different from most other lists (3, 6, 7, 8, 9, 10, 11, 12, 14, 15, 16, 17, 18, 19, 20, 21, 22, 23, 24, and 25). Similarly list 2 was found to be significantly different from lists 18, 19, 20, 22, 23 and 25 and list 5 was different from lists 10, 12, 15, 16, 17, 18, 19, 20, 22, 23, 24 and 25. Apart from these lists, all other lists differ from only a few other lists. For example, list 8 was significantly different from list 23; list 14 was significantly different from list 23. List 11 was significantly different from list 20.

Table 4.3

Comparison of SNR-50 across 25 sentences lists using Wilcoxon Signed-rank test in group II

L Lists (A)	Lists that are statistically different from A
L 1	L3(-2.41*), L4(-2.44*), L6(2.81**), L7(-1.99*),L8(-1.99*), L9(-2.80**), L10(-2.02*), L11(-1.96*),L12(-2.67**), L13(-2.53*), L14(-2.65**), L15(-2.66**),L16(-2.60**), L17(-2.68**), L18(-2.80**), L19(-2.56), L20(-2.87**), L21(-2.25*), L22(-2.68**), L23(-2.67**), L24(-2.25*), L25(-2.49*)
L 2	L4(-2.13*), L4(-2.80**), L9(-2.53*), L12(-2.68**), L13(-2.56*),L14(-2.60), L15(-2.22*), L16(-2.65**), L17(-2.81*), L18(-2.52*), L19(-2.39*), L20(-2.55*), L21(-2.13*), L22(-2.53*), L23(-2.67**), L24(-2.03*), L25(-2.25*)
3	L6(-2.65**), L9(-2.43*), L13(-2.02), L17(-2.50*), L18(-2.67**), L20(-2.68**), L23(-2.46*)
5	L6(-2.80**), L9(-2.31*), L17(-2.37), L18(-2.25*), L23(-1.99*)
	L10(-2.38*), L11(-2.43*), L12(-2.53*),L14(-2.38*),

6	L15(-2.20*), L16(-1.98*), L19(-2.82**), L21(-2.31*), L22(-2.54*), L24(-2.08*), L25(-2.33*)
10	L18(-2.04*), L23(-1.99*)
11	L17(-2.04*), L18(-2.38*)
13	L18(-2.09*)
15	L18(-2.10*)
17	L19(-2.31*)
18	L22(-2.31*), L24(-2.59**), L25(-2.08*)
20	L22(-2.41*)
22	L23(-1.97*)

Note: Only the significant differences are given in the table; L denotes lists; the numeric denotes the number of list. Z value for each comparison is given within parentheses next to the corresponding list. denotes p< 0.05; ** denotes p <0.01*

It can be observed from the Table 4.3 that most of the lists did not have statistically significant differences in SNR-50 scores from other lists in Group II. A few lists like Lists 1, 2, 3, 5, 6 were found to be significantly different from many other lists. List 1 is significantly different from most other lists 3, 4, 6, 7, 8, 9, 10, 11, 12, 13, 14, 15, 16, 17, 18, 19, 20, 21, 22, 23, 24, and 25. Similarly List 2 was found to be significantly different from lists 4, 6, 9, 12, 13, 14, 15, 16, 17, 18, 19, 20, 21, 22, 23, 24 and 25. List 3 is significantly different from lists 6, 9, 13, 17, 18, 20 and 23. List 5 was different from lists 6, 9, 17, 18 and 23. List 6 was different from many lists 10, 11, 12, 14, 15, 16, 19, 21, 22, 24 and 25. Apart from these lists, all other lists differed significantly from only one or two lists. List 10 differed from list 18 and 23. List 11 differed from list 17 and 18. Lists 13 differed from 18.List 15 also differed significantly from 18. List 17 was statistically different from 19. List 18 differed significantly from 22, 24 and 25. Lists 20 and lists 22 differed significantly from list 22 and 23 respectively.

Table 4.4
Comparison of SNR-50 across 25 sentences lists using Wilcoxon Signed-rank test in the group III

Lists (A)	Lists that are statistically different from A
L1	L3(-2.13*), L4(-2.72**), L5(-2.56*), L8(-2.10*) L10(-2.39*), L13(-2.10*),L14(-2.37*), L15(-2.55*), L16(-2.20*), L17(-2.60**), L18(-2.20*), L19(-2.57**), L20(-2.55*), L21(-2.20*), L22(-2.65**), L23(-2.62**), L24(-2.71**), L25(-2.81**)
L2	L4(-2.50*), L13(-1.98*),L14(-2.19*),L16(-2.40*), L17(-2.38*), L22(-2.39*), L23(-2.44*)L24(-2.68**), L25(-2.60**)
L3	L17(-2.03*), L23(-1.98*), L25(-2.32*)
L4	L8(-2.16*), L11(-2.55**), L12(-2.72**),
L5	L25(-1.97*)
L6	L11(-2.36*), L12(-2.15*)
L7	L17(-2.40*), L21(-2.31*), L25(-2.53*)
L8	L25(-2.20*)
L9	L17(-2.56*), L24(-1.98*)
L10	L11(-2.11*), L17(-2.12*), 25(-2.05*)
L11	L13(-2.53*), L14(-2.49*), L15(-2.60**), L16(-2.61**), L17(2.49*), L18(-1.96*), L19(-2.44*), L20(-2.39*), L21(-2.20*), L22(-2.82**), L23(-2.49*), L24(-2.61**), L25(-2.68**)
L12	L16(-2.33*), L17(-2.20*), L21(-2.30*), L22(-2.62**), L23(-1.77*), L24(-1.99*), L25(-2.37*)

Note: Only the significant differences are given in the table; L denotes lists; the numeric denotes the number of list. Z value for each comparison is given within parentheses next to the corresponding list. denotes p< 0.05; ** denotes p<0.01*

It can be seen in the Table 4.4, even in Group III that most of the lists did not have statistically significant differences in SNR-50 scores from other lists in Group III. A few lists like Lists 1, 2, 11, 12 were found to be significantly different from many other lists. List 1 was significantly different from most other lists 3, 4, 5, 8, 10, 11, 12, 13, 14, 15, 16, 17, 18, 19, 20, 21, 22, 23, 24, and 25. Similarly list 2 was found to be significantly different from lists 4, 13, 14, 16, 17, 22, 23, 24 and 25. List 11 was different from lists13, 14, 15, 16, 17, 18, 19, 20, 21, 22, 23, 24 and 25. List 12 was different from many lists 16, 17, 21, 22, 23, 24 and 25. Apart from these lists, a few lists were significantly different from one or two lists. For example, list 3 was significantly different from list 17, 23 and 25; list 4 was significantly different from list 8, 11 and 12. List 6 differed significantly from lists 11 and 12 and list 7 differed significantly from list 17, 21 and 25.Lists 9 was significantly different from lists 17 and 24 while list 10 differed statistically from lists 11, 17 and 25.

4.2. Comparison of SNR-50 across different groups

In order to check if the SNR-50 obtained by individuals with different degrees of hearing loss (i.e., mild moderate, moderately severe)) were significantly different or not, Krushkal-Wallis test was done. The test statistic and levels of significance for comparison of groups across each of the 25 lists are given in Table 4.5.

Table 4.5

Comparison of SNR-50 across different groups using Krushkal-Wallis test

Lists	χ^2	***p***	**Lists**	**χ2**	***P***
L1	7.44	.024*	**L14**	7.40	.025*
L2	9.81	.007**	**L15**	10.50	.005**
L3	10.29	.006**	**L16**	8.77	.012*
L4	6.78	.034*	**L17**	6.77	.034*
L5	8.10	.017*	**L18**	8.71	.013*
L6	6.96	.031*	**L19**	10.75	.005**
L7	10.55	.005**	**L20**	8.68	.013*
L8	8.61	.013*	**L21**	7.97	.019*
L9	8.81	.012*	**L22**	9.79	.007**
L10	10.45	.005**	**L23**	9.31	.010*
L11	10.86	.004**	**L24**	9.06	.011*
L12	11.16	.004**	**L25**	9.99	.007**
L13	6.15	.046*			

Note: L denotes lists; the numeric denotes the number of list. Z value for each comparison is given within parentheses next to the corresponding list. denotes p< 0.05; ** denotes p<0.01*

From the Table 4.2, it can be observed that there was a statistically significant difference among the groups in all the lists tested. Hence Mann-Whitney U test was performed to aid in the pair-wise comparison between groups.

Table 4.6

Pair-wise comparison of groups across 25 sentence lists using Mann-Whitney U test (Z values)

Lists	Z value		
	Group I vs II	**Group I vs III**	**Group II vs III**
L1	20.0*	20.5*	35.5
L2	15.0**	15.0**	40.0
L3	14.0**	16.0*	34.0
L4	20.5*	20.5*	50.0
L5	17.5*	21.0*	35.0
L6	22.0*	19.5*	40.5
L7	15.5**	11.0**	48.5
L8	19.5*	14.0**	49.5
L9	22.0*	12.5**	41.5
L10	12.0**	15.0**	46.0
L11	14.5**	11.0**	47.0
L12	15.0**	9.5**	49.0
L13	21.0*	23.0*	46.5
L14	19.0*	20.5*	40.5
L15	12.5**	14.5**	43.5
L16	16.0*	17.0*	47.0
L17	21.0*	20.0*	48.5
L18	21.5*	13.5**	40.5
L19	13.0**	13.0**	43.5
L20	17.5*	16.0*	44.0
L21	16.5*	21.5*	39.0
L22	13.5**	18.5*	35.0
L23	16.0*	15.0**	45.5
L24	15.0**	18.0*	40.5
L25	13.5**	16.5*	40.0

Note: Group I: mild hearing loss; Group II: moderate hearing loss; Group III: Moderately severe hearing loss; denotes p< 0.05; ** denotes p<0.01.*

The results revealed that the SNR-50 scores were significantly different between the mild and the moderate hearing loss group, and between the mild and moderately severe hearing loss group. However, there were no statistically significant differences in the SNR-50 scores between the moderate and the moderately severe groups for any of the 25 lists. In addition, the results of reliability check showed a very good reliability.

CHAPTER 5

DISCUSSION

The present study compared SNR-50 across 25 lists of Kannada sentence identification test in the presence of 4-talker babble in individuals with different degrees of hearing loss (mild, moderate and moderately-severe). In addition to list-wise comparison, group-wise comparisons of SNR-50 were performed across three groups with mild, moderate and moderately-severe hearing loss respectively.

5.1. Comparison of SNR-50 across 25 lists

The results of the current study showed that the SNR-50 in most of the lists was similar. However, a few lists were found to vary significantly from many other lists. Specifically lists 1, 2 and 5 in the group with mild hearing loss, lists 1, 2, 3, 5, 6 in the group with moderate hearing loss, and lists 1, 2, 11, 12 in the group with moderately-severe hearing loss were found to be significantly different from many other lists. Despite these differences among lists, the mean SNR-50 across the 25 lists within any group was very similar and comparable except for list 1 (as shown in Table 4.1). Studies examining the performance of hearing impaired individuals on QuickSIN (McArdle & Wilson, 2006; Wilson, McArdle & Smith, 2007; McArdle, Wilson & Burks, 2000) exhibit a similar trend as exhibited in the current study. The comparison is worthwhile as QuickSIN was the adopted format in converting Kannada Sentence Identification test in quiet to a multiple SNR adaptive speech in noise test. Both the procedures thus use the same background noise (four-talker babble) and similar administration and scoring procedures.

Inter-list variability among individuals with hearing loss is one of the findings of the current study. A similar finding also emerged in a study examining homogeneity of the 18

QuickSIN lists where the mean recognition showed high performance variability in the hearing impaired group, an effect that was not seen in normal hearing listeners. (McArdle & Wilson, 2006). A second observation in the present study is a high standard deviation of mean SNR-50 scores. Similar results were obtained in a study by Wilson, McArdle and Smith in 2007 evaluating the differences in performance of normal hearing listeners and hearing impaired listeners across four different speech in noise materials including the QuickSIN. List 1 and list 8 of QuickSIN test were used to obtain SNR-50 in 72 hearing impaired listeners who had pure-tone averages between 20 to 60 dB HL in the test ear. The mean SNR-50 using lists 1 and 8 of QuickSIN were found to be 12.5 dB SNR with an SD of 5.4 dB and 12.0 dB SNR with an SD of 5.2 dB respectively. Another study by McArdle et al. (2005) utilizing List 3 and list 4 of QuickSIN also reports a mean SNR-50 of 13.3 dB SNR with an SD of 5.0dB and 10.1dB SNR with an SD of 4.8 dB for a similar group of listeners with hearing loss. Thus, the variability of mean SNR-50 in such populations could also be due to individual listener differences and limited samples in each group (McArdle & Wilson, 2006).

5.2. Comparison of SNR-50 across groups

SNR-50 obtained by individuals with mild hearing loss was significantly different than those with both moderate and moderately-severe hearing loss. The mean SNR-50 in this group ranged from approximately -1.5 dB to about 0.5 dB for most of the lists. The significantly better performance of the group with mild hearing loss when compared to groups with higher degrees of hearing loss could also be explained on the basis of outer and inner hair cell loss. Intact outer and inner hair-cells are vital for normal sound /speech perception. It is a known fact that outer hair cells act as cochlear amplifier that amplifies soft sounds and also improves fine tuning while inner hair cell are directly involved in encoding the feature of sound or speech. Thus, the loss of outer hair cells predominantly cause reduced audibility of sound or speech cues. However, a loss of inner hair cells causes loss of vital speech cues or distortion of incoming sound or speech. Histological findings by Schuknecht (1993) involving post mortal cochlear examination attempts to correlate inner hair cell loss with hearing loss. It was found that for thresholds of 40 dB HL and below, no inner hair-cell loss was evident.

Another study on experimental animals reveals significant inner hair cell loss could be evident only a loss above 50 dB HL with only outer hair cell damages accounted for losses less than 50 dB HL (Stebbins, Hawkins, Johnson & Moody, 1979). Thus, individuals with a mild hearing loss might predominantly suffer from reduced audibility in contrast to higher degrees of hearing loss which might involve partial or total loss of inner hair cells giving an edge to individuals with mild hearing loss in speech in noise perception (Killion & Niquette, 2000).

Another finding was that SNR-50 was not statistically different between individuals with moderate and moderately-severe hearing loss. Geetha et al. (2014) found a difference in speech identification scores in quiet between moderate and moderately-severe hearing loss groups using the Kannada sentence test. They reported that their speech identification materials using sentence length stimuli are also known to exhibit a trend of decreasing scores as the degree of hearing loss increases making them sensitive to the same. In the current study, the same material was used in the presence of noise.

The ability to perceive speech in noise is highly variable even in individuals with similar pure-tone sensitivities (Killion & Niquette, 2000).This phenomenon can be better understood by analyzing the cellular mechanics in speech or sound perception. Speech understanding in noise requires the normal functioning of outer hair cells, inner hair cells and auditory neurons. In individuals with hearing loss, there could be a loss of outer hair cells or inner hair cells or both. A loss of outer hair cells causes reduced sensitivity or audibility while inner hair cell loss causes distortion and lack of speech cues vital for perception. Thus, an individual with inner hair cell loss may have some difficulty perceiving speech in quiet, but perceiving speech in noise is almost always challenging (Killion, 1997).

Studies relating SNR loss to pure-tone loss also lend support to the results of the current study. Three different data sets, relating hearing loss and SNR loss obtained using three different speech in noise materials are available. These include the Danish logatomes which uses CVCV words in speech-spectrum noise, the HINT which uses sentences in a speech spectrum noise and The SIN test which uses four talker babble as masker. It was found that in all of these materials the SNR loss could not be reliably predicted as the SNR loss was found to span a 15 to 20 dB range even in individuals with similar pure-tone losses (Lyregaard, 1982; Nilsson, Soli & Sullivan, 1994; Hanks & Johnson, 1998).This offers support to the trend of overlapping recognition performance between the moderate and moderately-severe group observed in the current study.

CHAPTER 6

SUMMARY AND CONCLUSION

The use of native, sentence level speech material, and adaptive procedures for the clinical measurement of speech perception in noise are considered to be the most valid, reliable and representative tool. The Kannada Sentence Identification test developed by Geetha et al. in 2014 is a speech identification measure administered in quiet and uses a key word response for scoring. Like any other speech measure in quiet, it is prone to ceiling and floor effects and provides only limited insight into difficulties experienced by an individual with hearing impairment in a real life listening environments.

The present study aimed to convert the Kannada sentence identification test developed by Geetha et al. 2014 into SNR-50 format and investigate the list equivalency across different degrees of hearing loss. The study also aimed to compare SNR-50 across three degrees of sensorineural hearing loss namely mild, moderate and moderately-severe hearing loss. A standard group comparison design was used for the same.

The sentences in each of the 25 lists of the Kannada Sentence Identification test were mixed with four-talker babble to yield 10 different SNRs viz. -7, - 4, -1, 2, 5, 8, 11, 14, 17 and 20 dB SNR. These sentence in babble stimuli were used to obtain SNR at 50% correct recognition performance (SNR-50). The SNR-50 was compared across 25 lists and also across three different degrees of hearing loss.

The results revealed that most of the lists were not statistically different from other lists in all groups except a few lists thereby indicating equivalency of the material in noise. Lists 1, 2, 3, 5, 6, 11 and 12 were found to significantly different from many other lists. A similar trend is well documented in studies examining the performance of hearing impaired individuals QuickSIN test. Hence, the differences are also attributable to individual listener differences and limited samples in each group rather than just heterogeneity of lists.

Inter-group comparisons revealed that the SNR-50 was significantly better in the mild group than both moderate and moderately-severe groups. However, the mean recognition performance was not statistically different between groups with moderate and moderately-severe hearing loss.

To conclude, the sentence in noise material developed using the sentences of Kannada sentence identification test has a large number of lists that result in similar SNR-50 values though the variability of performance in the hearing impaired group and less number of samples produced higher standard deviations. In addition the material is also sensitive to degree of hearing loss.

6.1. Clinical Implications:

- These validated lists will enable clinicians to assess sentence recognition in noise in individuals with hearing loss in the most natural and representative approximation of daily listening environments.
- The material can be conveniently used for research when multiple conditions are to be tested without the risk of familiarization and practice effect.

6.2. Future Directions:

- Similar studies can be conducted with large number of samples in each of the mild, moderate and moderately-severe groups.
- Studies comparing performance of age matched normal hearing and hearing impaired individuals on the test material will be useful.

REFERENCES

Avinash, M. C., Meti, R., & Kumar, U. (2010). Development of sentences for Quick Speech-In-Noise (QuickSIN) Test in Kannada. *Journal of Indian Speech and Hearing Association*, *24*(1), 59-65.

Beattie, R. C. (1989). Word recognition functions for the CID W-22 test in multitalker noise for normally hearing and hearing-impaired subjects. *Journal of Speech and Hearing Disorders*, *54*(1), 20-32.

Bentler, R. A. (2000). List equivalency and test-retest reliability of the speech in noise test. *American Journal of Audiology*, *9*(2), 84-100.

Bray, V., & Nilsson, M. (2002). What digital hearing aids can do: Another perspective. *The Hearing Journal*, *55*(4), 60-61.

Carhart, R. (1965). Problems in the measurement of speech discrimination. *Archives of Otolaryngology*, *82*(3), 253-260.

Cohen, R. L., & Keith, R. W. (1976). Use of low-pass noise in word-recognition testing. *Journal of Speech, Language, and Hearing Research*, *19*(1), 48-54.

Cooper, J. C., & Cutts, B. P. (1971). Speech discrimination in noise. *Journal of Speech, Language, and Hearing Research*, *14*(2), 332-337.

Cox, R. M., Alexander, G. C., & Gilmore, C. (1987). Development of the Connected Speech Test (CST). *Ear and Hearing*, *8*(5), 119s.

Cox, R. M., Alexander, G. C., Gilmore, C., & Pusakulich, K. M. (1988). Use of the Connected Speech Test (CST) with hearing-impaired listeners. *Ear and Hearing*, *9*(4), 198-207.

Cox, R. M., Gray, G. A., & Alexander, G. C. (2001). Evaluation of a Revised Speech in Noise (RSIN) test. *Journal of the American Academy of Audiology*, *12*(8), 423-433.

Delattre, P. (1964). Comparing the vocalic features of English, German, Spanish and French. *IRAL-International Review of Applied Linguistics in Language Teaching*, *2*(1), 71-98.

Dirks, D. D. (1982). Comments regarding "Speech discrimination ability in the hearing impaired". *The Vanderbilt hearing-aid report II: State of the art research needs*, 44-50.

Dirks, D. D., Morgan, D. E., & Dubno, J. R. (1982). A procedure for quantifying the effects of noise on speech recognition. *Journal of Speech and Hearing Disorders*, *47*(2), 114-123.

Dubno, J. R., Dirks, D. D., & Morgan, D. E. (1984). Effects of age and mild hearing loss on speech recognition in noise. *The Journal of the Acoustical Society of America*, *76*(1), 87-96.

Duncan, K. R., & Aarts, N. L. (2006). A comparison of the HINT and Quick Sin Tests. *Journal Of speech Language Pathology and Audiology*, *30*(2), 86.

Fifer, R. C., Jerger, J. F., Berlin, C. I., Tobey, E. A., & Campbell, J. C. (1983). Development of a dichotic sentence identification test for hearing-impaired adults. *Ear and hearing*, *4*(6), 300-305.

Findlay, R. C. (1976). Auditory dysfunction accompanying noise-induced hearing loss. *Journal of Speech and Hearing Disorders*, *41*(3), 374-380.

Gatehouse, S. (1992). The time course and magnitude of perceptual acclimatization to frequency responses: Evidence from monaural fitting of hearing aids. *The Journal of the Acoustical Society of America*, *92*(3), 1258-1268.

Geetha, C., Kumar, K. S. S., Manjula, P., & Pavan, M. (2014). Development and standardisation of the sentence identification test in the Kannada language. *Journal of Hearing Science*, *4*(1), 18-26.

Grant, K. W., & Walden, T. C. (2013). Understanding excessive SNR loss in hearing-impaired listeners. *Journal of the American Academy of Audiology*, *24*(4), 258-273.

Hirsh, I. J., Davis, H., Silverman, S. R., Reynolds, E. G., Eldert, E., & Benson, R. W. (1952). Development of materials for speech audiometry. Journal of Speech and Hearing Disorders, 17(3), 321-337.

Hudgins, C. V., Hawkins, J. E., Kaklin, J. E., & Stevens, S. S. (1947). The development of recorded auditory tests for measuring hearing loss for speech. *The Laryngoscope*, *57*(1), 57-89.

Jain, C., Narne, V. K., Singh, N. K., Kumar, P., & Mekhala, M. (2014). The Development of Hindi Sentence Test for Speech Recognition in Noise. *International Journal of Speech & Language Pathology and Audiology*, *2*(2), 86-94.

Kalikow, D. N., Stevens, K. N., & Elliott, L. L. (1977). Development of a test of speech intelligibility in noise using sentence materials with controlled word predictability. *The Journal of the Acoustical Society of America*, *61*(5), 1337-1351.

Keith, R. W., & Talis, H. P. (1972). The effects of white noise on PB score of normal and hearing-impaired listeners. *Audiology*, *11*(3-4), 177-186.

Killion, M. C. (1997). Hearing aids: Past, present, future: Moving toward normal conversations in noise. *British Journal of Audiology*, *31*(3), 141-148.

Killion, M. C. (1997). SNR loss: I can hear what people say, but I can't understand them. *The Hearing Review*, *4*(12), 8-14.

Killion, M. C., & Christensen, L. A. (1998). The case of the missing dots: Al and SNR loss. *The Hearing Journal*, *51*(5), 32-34.

Killion, M. C., & Niquette, P. A. (2000). What can the pure-tone audiogram tell us about a patient's SNR loss? *The Hearing Journal*, *53*(3), 46-48.

Killion, M. C., & Villchur, E. D. G. A. R. (1993). Kessler was right-partly: But SIN test shows some aids improve hearing in noise. *Hearing Journal*, *46*, 31-31.

Killion, M. C., Niquette, P. A., Gudmundsen, G. I., Revit, L. J., & Banerjee, S. (2004). Development of a quick speech-in-noise test for measuring signal-to- noise ratio loss in normal-hearing and hearing-impaired listeners. *The Journal of the Acoustical Society of America*, *116*(4), 2395-2405.

Kollmeier, B., & Wesselkamp, M. (1997). Development and evaluation of a German sentence test for objective and subjective speech intelligibility assessment. *The Journal of the Acoustical Society of America*, *102*(4), 2412-2421.

Kuzniarz, J. (1973). Hearing loss and speech intelligibility in noise. In *Proceedings of the International Congress on Noise as a Public Health Problem* (pp. 57-71).

Lecumberri, M. L. G., Cooke, M., & Cutler, A. (2010). Non-native speech perception in adverse conditions: A review. *Speech Communication*, *52*(11), 864-886.

Leshowitz, B. (1977). Speech intelligibility in noise for listeners with sensorineural hearing damage. *IPO annual progress report*, *12*(1), 1-25.

Lyregaard, P. E. (1981). Frequency selectivity and speech intelligibility in noise. *Scandinavian audiology. Supplementum*, *15*, 113-122.

Mayo, L. H., Florentine, M., & Buus, S. (1997). Age of second-language acquisition and perception of speech in noise. *Journal of speech, language, and hearing research*, *40*(3), 686-693.

McArdle, R. A., & Wilson, R. H. (2006). Homogeneity of the 18 QuickSIN™ lists. *Journal of the American Academy of Audiology*, *17*(3), 157-167.

McArdle, R. A., Wilson, R. H., & Burks, C. A. (2005). Speech recognition in multitalker babble using digits, words, and sentences. *Journal of the American Academy of Audiology*, *16*(9), 726-739.

Miller, G. A., Heise, G. A., & Lichten, W. (1951). The intelligibility of speech as a function of the context of the test materials. *Journal of experimental psychology*, *41*(5), 329.

Mueller, H. G. (2001). Speech audiometry and hearing aid fittings: Going steady or casual acquaintances?. *The Hearing Journal*, *54*(10), 19-29.

Niemeyer, W. (1965). Speech audiometry with phonetically balanced sentences. *International Audiology*, *4*(2), 97-101.

Nilsson, M., Soli, S. D., & Sullivan, J. A. (1994). Development of the Hearing in Noise Test for the measurement of speech reception thresholds in quiet and in noise. *The Journal of the Acoustical Society of America*, *95*(2), 1085-1099.

Plomp, R. (1978). Auditory handicap of hearing impairment and the limited benefit of hearing aids. *The Journal of the Acoustical Society of America*, *63*(2), 533-549.

Plomp, R. (1986). A signal-to-noise ratio model for the speech-reception threshold of the hearing impaired. *Journal of Speech, Language, and Hearing Research*, *29*(2), 146-154.

Plomp, R., & Mimpen, A. M. (1979). Improving the reliability of testing the speech reception threshold for sentences. *Audiology*, *18*(1), 43-52.

Rogers, C. L., Lister, J. J., Febo, D. M., Besing, J. M., & Abrams, H. B. (2006). Effects of bilingualism, noise, and reverberation on speech perception by listeners with normal hearing. *Applied Psycholinguistics*, *27*(03), 465-485.

Rosen, S., Souza, P., Ekelund, C., & Majeed, A. A. (2013). Listening to speech in a background of other talkers: Effects of talker number and noise vocoding. *The Journal of the Acoustical Society of America*, *133*(4), 2431-2443.

Silverman, S. R., & Hirsh, I. J. (1955). CX Problems Related to the Use of Speech in Clinical Audiometry. *Annals of Otology, Rhinology & Laryngology*, *64*(4), 1234-1244.

Soli, S. D., & Wong, L. L. (2008). Assessment of speech intelligibility in noise with the Hearing in Noise Test. *International Journal of Audiology*, *47*(6), 356-361.

Speaks, C., & Jerger, J. (1965). Method for measurement of speech identification. *Journal of Speech, Language, and Hearing Research*, *8*(2), 185-194.

Sperry, J. L., Wiley, T. L., & Chial, M. R. (1997). Word recognition performance in various background competitors. *Journal-American Academy of Audiology*, *8*, 71-80.

Tanniru, K., Narne, V. K., Jain, C., Konadath, S., Singh, N. K., & Sreenivas, K. R. (2017). Development of equally intelligible Telugu sentence-lists to test speech recognition in noise. *International Journal of Audiology*, 1-8.

Taylor, B. (2003). Speech-in-noise tests: How and why to include them in your basic test battery. *The Hearing Journal*, *56*(1), 40-42.

Tyler, R. S., Gagne, J. P., & Tye, N. (1994). The use of speech-perception tests in audiological rehabilitation: Current and future research needs. *Journal of the Academy of Rehabilitative Audiology*, *27*(Mono. Suppl.), 47-66.

Van Engen, K. J., & Bradlow, A. R. (2007). Sentence recognition in native-and foreign-language multi-talker background noise a. *The Journal of the Acoustical Society of America*, *121*(1), 519-526.

Walden, T. C., & Walden, B. E. (2004). Predicting success with hearing aids in everyday living. *Journal of the American Academy of Audiology*, *15*(5), 342-352.

Willeford, J. A. (1968). Competing messages for diagnostic purposes. *Colorado State University, Fort Collins, Colo*.

Willott, J. F. (1991). *Aging and the auditory system: Anatomy, physiology and psychophysics*. Whurr Pub Ltd.

Wilson, R. H. (2003). Development of a speech-in-multitalker-babble paradigm to assess word- recognition performance. *Journal of the American Academy of Audiology*, *14*(9), 453- 470.

Wilson, R. H., & McArdle, R. (2005). Speech signals used to evaluate functional status of the auditory system. *Journal of rehabilitation research and development*, *42*(4), 79.

Wilson, R. H., & Strouse, A. (2002). Northwestern University Auditory Test No. 6 in multi- talker babble: a preliminary report. *Journal of rehabilitation research and development*, *39*(1), 105.

Wittkop, T., Albani, S., Hohmann, V., Peissig, J., Woods, W. S., & Kollmeier, B. (1997). Speech processing for hearing aids: Noise reduction motivated by models of binaural interaction. *Acta Acustica united with Acustica*, *83*(4), 684-699.

Yathiraj, A. & Vijayalakshmi, C. S. (2005). Phonemically Balanced Word list in Kannada. Departmental project, Developed at the Department of Audiology, AIISH, Mysuru.