DEVELOPMENT OF LOW FREQUENCY WORD LISTS FOR SPEECH IDENTIFICATION TEST IN MANIPURI LANGUAGE

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MAY, 2014

DEDICATED TO MY BELOVED PARENTS ☺

CERTIFICATE

This is to certify that this dissertation entitled "**DEVELOPMENT OF LOW FREQUENCY WORD LISTS FOR SPEECH IDENTIFICATION TEST IN MANIPURI LANGUAGE**" is a bonafide work submitted in part fulfillment for the degree of Master of Science (Audiology) of the student (**Registration No. 12AUD020)**. This has been carried out the under guidance of a faculty of this institute and has not been submitted earlier to any other university for the award of any Diploma or Degree.

Mysore

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CERTIFICATE

This is to certify that dissertation entitled "**DEVELOPMENT OF LOW FREQUENCY WORD LISTS FOR SPEECH IDENTIFICATION TEST IN MANIPURI LANGUAGE**" has been prepared under my supervision and guidance. It is also certified that this dissertation has not been submitted earlier to any other university for the award of any diploma or degree.

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DECLARATION

This is to certify that this master's dissertation entitled "**DEVELOPMENT OF LOW FREQUENCY WORD LISTS FOR SPEECH IDENTIFICATION TEST IN MANIPURI LANGUAGE"** is the result of my own study under the guidance of a faculty at All India Institute of Speech and Hearing, Mysore, and has not been submitted earlier to any other university for the award of any Diploma or Degree.

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Chapter 1

Introduction

Speech is the most common means of communication used by humans. Speech perception is a specialized aspect of a general human ability to seek and recognize patterns (Raphael, Borden, Katherine, & Harris, 2006). In other words, Speech perception is defined as the process of decoding a message from a stream of sounds coming from a speaker (Borden & Harris, 1980). Speech sounds have come to occupy an important place among the auditory stimuli that are used in clinical audiometry (Hirsh, Davis, Silverman, Reynolds, Eldert, & Bemson, 1952). ASHA (1978) pointed out that the pure tone average gets validated when it is correlated with the speech threshold. Pure tone audiometry does not provide complete understanding of a persons' communication deficit; hence it alone is inadequate in diagnosis and differential diagnosis of certain auditory dysfunction (Kholia, 2010).

It is well documented that speech understanding cannot be accurately predicted based upon pure tone thresholds (Martin & Clark, 2011). An individual with relatively poor pure tone thresholds may perform surprisingly well on speech understanding tasks, whereas a person with relatively good or even normal pure tone thresholds may complain of difficulty hearing and understanding speech or may exhibit unexpectedly poor speech discrimination ability (Martin & Clark, 2011). Speech audiometry gives more diagnostic and corroborative information than what is provided by pure tone audiometry alone. Hence, it is logical that speech audiometry also be included as a part of hearing assessment (Martin & Clark, 2011).

Speech audiometry measures a person's ability to use his/her hearing in ways that are closer to everyday auditory experience (Hirsh, Davis, Silverman, Reynolds, Eldert, & Benson, 1952). Speech audiometry entails measurement of an individual's ability to hear and understand speech and therefore becomes an important part of the audiological diagnosis of hearing impaired individual. Speech audiometry has not only added a kind of validity to pure tone audiometry, but also certain tests that have appeared to have diagnostic and prognostic value as well (Hirsh et al., 1952). Knowledge gained from the use of speech audiometry is also helpful in the diagnosis of site of lesion in the auditory system as well as in aural rehabilitation (Martin & Clark, 2011).

Speech audiometry tests like speech detection threshold (SDT), speech reception/recognition thresholds (SRT), speech identification score (SIS), Most comfortable loudness level (MCL), Discomfort level etc. are the few examples of frequently used speech audiometry tests which are proven to have diagnostic and prognostic value. For finding speech detection threshold (SDT), sentences are more preferable than isolated words or phrases. For speech recognition threshold (SRT), spondaic words, paired words, sentences and conversations can be used (Hudgins, Hawkins, Karlin, & Stevens, 1947; Carhart 1971). Phonetically balanced words (PB words) can be used for speech identification test whereas measurement of MCL should be made with a continuous discourse stimulus so that the patient has an opportunity to listen to speech as it fluctuates over time (Eldert, Davis, & Lehiste, 1951). The speech spectrum shows that speech sounds such as stops (/b/, /d/, /m/, /n/, /g/), liquids (/l/, /r/) semivowels (/v/, /j/) and vowels (/u/,/a/) are in the low frequency (< 1kHz) and affricates and fricatives at mid to high frequencies (Northern & Downs, 1984; Ling, 1989). The vowel sounds, which is typically low frequency sounds make up the loudness of speech (Sataloff & Linville 2006). Loudness play important role in speech perception as loss of audibility was the major factor contributing to speech perception (Humes & Roberts, 1987, 1990). According to Bothroyd 1971, individuals had no difficulty with vowel discrimination unless their hearing loss was severe enough to make certain portions of the vowel audible. There are a variety of conditions which results in low frequency hearing loss, some of which are Meniere's disease (Opheim & Flottrop, 1957), viral infections (Djupseland, Flottorp, Degre, & Stien, 1979), poor cochlea development and congenital cholesteatoma.

A person with a hearing loss is bound to have difficulty in perception of speech sounds. The kind and degree of perceptual difficulty depends on several factors which includes degree of hearing loss, type of hearing loss, and configuration of the audiogram (Gardner, 1971; Jerger & Jerger, 1971; Pascoe, 1975; Owens & Schubert, 1977). Depending on the audiogram pattern, the speech perception ability would vary. A person with a high frequency or low frequency hearing loss would have difficulty in perceiving sounds having energy at high frequency region and low frequency region respectively (McDermott & Dean, 2000). Presence of sensorineural hearing loss may reduce the contribution of speech information in a given frequency region to speech understanding that SNHL has a differential effect on the contribution of speech information depending on the frequency region where the hearing loss occurs (Pavlovic, Studebaker, & Scherbecoe, 1986; Studebaker, Scherbecoe, McDaniel, & Gray, 1997). The speech perception varied depending on whether the person has different audiogram configuration like gradually or sharply slopping, raising pattern, flat pattern etc. (Martin, 1987). A hearing loss involving only part of the auditory frequency range may go undetected in a speech test when it is not carefully controlled (Pascoe, 1975). Using regular speech stimulus in case of a person having sloping high frequency and raising low frequency hearing loss would be insensitive to identify the problem. According to Turner and Cummings (1999), the redundancy of natural speech can compensate for super threshold deficits when the hearing is mild to moderate in the low frequencies and high frequencies hearing loss. Hence, it is important that special word lists needs to be developed for testing different configuration of hearing loss to track the exact speech identification ability.

According to Berke (2011), individuals with low frequency hearing loss will have difficulty hearing sounds in the frequency range of 125 Hz to 1000 Hz and their speech perception ability will be poorer (Thornton & Abbas, 1980). One of the clues to a low frequency hearing loss is that they will also have difficulty hearing in group or in a noisy situation (Berke, 2011). Testing with low frequency word list help in giving a more accurate and reliable result in assessing such people. Hence, having low frequency speech material is very important.

High frequency speech materials in most of the Indian languages like Hindi and Urdu (Ramachandra, 2001), Kannada (Kavitha, 2002), Tamil (Sinthiya, 2009), English (Sudipta, 2006), Telugu (Ratnakar, 2010), and Manipuri (Margaret, 2012) have been developed. Manipuri is an official language spoken in the North- East Indian state Manipur and also partly spoken in Myanmar and Bangladesh. Speech materials available in Manipuri include wordlists for administering SRT and SIS (Tanuja, 1985), High frequency speech identification test (Margaret, 2012) and Bisyllabic wordlist for speech recognition threshold in Manipuri (Shah, 2013). Now, there is an evident need to develop low frequency word list especially for assessing people who have raising pattern of hearing loss and in selecting hearing aid. Low frequency speech material is not currently available in Manipuri language. This study aims at developing low frequency word lists in Manipuri language.

Need of the study

Manipuri also known as Meiteilon is the language spoken commonly in Manipur which is spoken by 56% of the total population. According to Hudgins, Hawkins, Karlin and Stevens (1947), speech testing materials should be in a patient's own language and dialect. Individual's perception of speech is influenced by his own mother tongue. Performance of non-native speakers was found to be consistently below that of native speakers (Ramkissoon, Proctor, Lansing, & Bilger, 2002). Hence, developing speech material in their native language is very essential.

According to Martin (1994), speech is highly redundant owing to the simultaneous transmission of the information in several ways. Hence, a hearing loss involving a limited part of the frequency range may not be detected in a speech test which is not carefully controlled. So, using regular stimulus for speech identification test may be insensitive towards identification of the problem of a person who has low frequency hearing loss. Not only this, low frequency word list would be useful in selecting appropriate hearing aid for people who have low frequency hearing loss. High frequency word lists in most of the Indian languages have been developed but low frequency word list is not yet been developed in any of the Indian language. In Manipuri language, speech materials like wordlist for administering SRT and SIS developed by Tanuja (1985), High frequency word list for speech identification test developed by Margaret (2012) and Bisyllabic wordlist for administering SRT Shah (2013) have already been developed; but, there is no low frequency word list for speech identification test which is very important especially for individuals with low frequency hearing loss. Hence, it is very essential to develop low frequency word list in Manipuri which would help in assessing the communication ability of individuals having low frequency hearing loss as well as in rehabilitation of such people.

Aim of the study

The study aims at developing low frequency monosyllabic word list in Manipuri language for administering speech identification test.

Objectives of the study

The objectives of the study are:

1) To develop two low frequency monosyllabic word lists in Manipuri language to determine speech identification score for adults.
2) To check the equivalence between the word lists selected.
3) To obtain the SIS scores by administering speech identification test on native Manipuri speakers who have normal hearing sensitivity.

Chapter 2

Review of literature

Speech is one of the most important vehicles of human communication. It is so important that it is considered to be the most characteristic feature of human race (Plomp, 2002). Speech communication covers a wide range of spoken material and takes place in a variety of contexts. Communication through speech reflects the critical activities of life and comprehension of social communication. Speech perception is the process of decoding a message from a stream of sounds coming from the speaker (Borden & Harris, 1980) and it is concerned with the listener's ability to perceive the acoustic waveforms produced by a speaker as a string of meaningful words and ideas (Goldinger, Pisonic, & Logan, 1991).

Speech sounds have come to occupy an important place among the auditory stimuli that are used in clinical audiometry. Speech audiometry has not only added a kind of validity to pure tone audiometry but also certain speech tests have appeared to have diagnostic and prognostic value as well (Hirsh et al., 1952). Pure tone audiometry provides only a partial picture about a patient's auditory sensitivity and it doesn't give any information about the ability to hear and understand speech (Martin & Clark, 2011). Speech audiometry measures an individual's ability to hear and understand speech. Speech understanding cannot be accurately predicted based on pure tone thresholds (Smoorenburg, 1992; Bosman & Smoorenburg, 1995) that an individual of relatively poor pure tone thresholds may performs surprisingly good on speech understanding tasks whereas a person of relatively good or even normal pure tone thresholds may perform poor in speech understanding task and complain of difficulty hearing and understanding speech. According to Young and Gibbons

(1962), although there was some degree of association between scores obtained from tests of speech understanding and pure tone thresholds, accurate prediction of speech understanding from pure tone thresholds cannot be obtained. ASHA (1978) pointed out that pure tone average gets validated when it is correlated with the speech threshold. Pure tone audiometry does not provide completed understanding of a person's communication deficit, and it alone gives inadequate information in diagnosis and differential diagnosis of certain auditory dysfunction (Kholia, 2010). Hence, speech audiometry plays a very important role as well as a mandatory part in the evaluation of hearing impaired individuals.

Generally speech audiometry tests consist of speech reception/recognition thresholds (SRT), speech identification score (SIS), speech detection threshold (SDT), threshold of tolerance or discomfort level. Various materials like nonsense syllable (Levitt & Resnick, 1978), sentences (Nilsson, Soli, & Sullivan, 1994), monosyllabic and bisyllabic words (Begum, 2000; Jijo & Yathiraj, 2008), and discourse are used for speech audiometry.

Importance of speech audiometry.

Since communication ability of two persons is not same and pure tone audiometry doesn't talk about the communication ability of a person, speech audiometry plays a major role in assessing communication ability of an individual. Speech audiometry is used to cross check the pure tone audiometry and validates the air condition thresholds (Carhart, 1952). It is the important part of the differential diagnostic battery as speech stimuli can be used to assess the status of auditory system (Thibodeau, 2007). Speech audiometry provides the clinician with valuable diagnostic evidence for the evaluation and management of hearing disorder (Sagon & Uchanski, 2006). For example, word recognition testing can be used to assess retro-cochlear function by testing whether intelligibility scores decrease significantly as the intensity increases. Speech audiometry is the best friend in the clinic for an audiological diagnosis (Kholia, 2010). Speech audiometry also provides an estimate of suprathreshold speech perception (Hannley, 1986). There are mainly three uses of speech audiometry; first, it is used to supply information in the initial analysis of a person's difficulty. Second, it is used in assessing the results of restorative surgery as well as medical treatment. Third, speech audiometry provides an important guide to the educational and rehabilitational management (Carhart, 1952). Speech audiometry gives better information than pure tone audiometry in assessing the actual hearing difficulties of an individual and also analyzes distortion of sounds, spatial localization, loudness and comprehension of speech (Martini, Mazzoli, Rosignoli, Trevisi, & Maggi, 2001). Speech audiometry also helps in selection of hearing aid as well as in aural rehabilitation and obtains progress in management process. It is also used to assess the performance of cochlear implants (Cowan, Deldot, Barker, Sarant, & Pegg, 1997). In identification of functional hearing loss and site of lesion, speech audiometry plays a major role. According to Gelfand, 2009, speech audiometry plays essential role in assessing hearing acuity of children and difficult to test population. Since we live in an oral-aural society, the most measurable aspect of human auditory function would be the ability to understand speech. Speech audiometry is generally regarded as the clinically more acceptable than pure tone audiometry for identifying patient with poor auditory function, because it involves the assessment of higher level linguistic activities and the effects of contextual constraints in processing auditory information (Wang, Mannell, Newall, Zhang, & Han, 2007). Hence, having speech audiometry in assessing a person's hearing difficulties is very essential. Speech sounds are composed of high, mid and low frequency sounds. Greenberg (1947) reported the importance of low frequency portion of speech signal and he stated that auditory system captures the temporally dynamic properties of speech through computation of the low frequency portion of the modulation spectrum and this low frequency modulation spectrum extract the syllabic and related phonetic information required for accessing higher level linguistic representations of the speech signal. Hence, it is observed that low frequency portion of a speech signal play an important role in the perception and understanding of speech.

Importance of low frequency energy.

Increase gain in low frequency area also improves audibility of weak low frequency sounds which result in increase in loudness and improvement of sound quality. Turner and Cummings (1999) reported data from one individual with severe low frequency hearing loss who did receive benefit from low frequency amplification. They further reported that when the audible speech was being provided at frequency regions as low as 300 Hz, speech recognition ability was improved when tested on 10 listeners with high frequency hearing loss.

Miller and Nicely (1955) reported that place of articulation information for speech is located primarily in the frequencies of 1000Hz and above, whereas a great deal of voicing information is present at lower frequencies. It is reported that providing audible speech information to frequency regions of 1500 Hz and below resulted improving speech recognition ability for the majority of the subjects who had hearing loss for frequencies less than 1500 Hz (Ching, Dillon, & Bryne, 1998). For individuals with moderate to severe flat SNHL, restoring audibility to low frequency speech information is more beneficial than restoring audibility to high frequency speech information (Ching, Dillon, & Byrne, 1998; Ching, Dillon, Katsch, & Byrne, 2001; Hogan & Turner 1998; turner & Cummings, 1999; Vickers, Moore, & Baer, 2001).

Turner and Brus (2001) opined that, majority of the individuals with low frequency hearing loss up to 75dBHL had improved speech perception ability when the speech information is made audible at 2800Hz and below. They further hypothesized that types of speech cues located in the high versus low frequencies are different and therefore it would be differentially affected by cochlear damage. For example, place of articulation cues is usually located in higher frequency regions which tend to be signaled by the specific frequency spectrum of speech signal, may not be transmitted effectively by cochlea containing regions of substantial inner hair cell loss; whereas, voicing cues which is encoded by amplitude variations, may not be affected by regions of inner hair cell loss as long as some intact inner hair cells remain. This would be the reason of getting different speech perception ability when speech information is made audible at different frequency regions.

Turner, Gantz, Vidal, Behrens and Henry (2004) studied the advantages of preserving low frequency acoustic hearing in cochlear implant individuals for understanding speech in the presence of background noise. A simulation experiment was performed using 15 normal hearing individuals. Two different background conditions were used, speech shaped steady noise and competing talkers. All the individuals received simulated processing of speech that is high frequency electrical stimulation was presented along with the acoustic low frequency hearing. Results showed a clear advantage for preserving low frequency residual hearing for speech understanding in the presence of background of other talkers, but not in steady noise condition. In addition to this, low frequency acoustic hearing allows an individual to perceive the fundamental frequencies of the talkers, separating the target speech from the background of other talkers.

Speech perception in individuals with hearing impaired.

Individuals with cochlear hearing loss complain frequently of difficulties in understanding speech. The extend of speech difficulties depend on the degree and configuration of hearing loss. Individuals with mild to moderate hearing loss do not have much problem in understanding speech in quiet situation, but have difficulty speech understanding in background noise whereas individuals with severe to profound hearing loss generally have severe problem of understanding speech in both quiet and noisy situation (Moore, 1998). Individuals with low frequency hearing loss also demonstrate poor speech recognition performance when low pass filtered speech materials were used (Thornton & Abbas, 1980). Speech perception ability also varies according to the configuration of hearing loss. Individuals having steeply sloping configuration would have difficulty perceiving speech sounds having energy at high frequency, whereas individuals having raising configuration would have difficulty perceiving speech having energy at low frequency region (Mc. Dermott & Dean, 2000). According to Turner and Brus (2001), individuals with sensorineural hearing loss often accompanied by reduced speech understanding ability due to elevated sensitivity thresholds. Presence of sensorineural hearing loss reduces the contribution of speech information in a given frequency region to speech understanding and sensorineural hearing loss has different effect on the contribution of speech information depending on the region where the hearing loss is present (Pavlovic, Studebaker, & Scherbecoe, 1986; Studebaker, Scherbecoe, McDaniel, & Gray, 1997). For example, in individuals with flat hearing loss, the contribution of speech was reduced equally across all the frequencies, whereas in individuals with high frequency hearing loss, contribution of speech information reduced in the regions where hearing loss was present. In summary, hearing loss would result in a frequency specific deficit in contribution of speech information. Vickers, Moore and Baer (2001) also found that individuals with high frequency dead regions made limited use of amplified high frequency speech information whereas without dead regions showed improvement in speech understanding ability when the low pass filter cutoff frequency was increased. Individuals with sensorineural hearing loss have poor speech understanding ability when the background noise are present due to reduction in the ability to resolve the frequency components of complex sounds and performed more poorly when listening in a fluctuating background sounds (Lorenzi, Gilbert, Garnier, & Moore, 2006). The lack of ability to use temporal fine structure in hearing impaired individuals would be the reason for getting poorer speech understanding when the background sounds are present. Zeng and Liu (2006) showed that individuals with auditory neuropathy also have poor speech understanding in the presence of background noise due to impaired temporal processing ability. Speech perception ability in noise exhibited by hearing impaired individuals is poorer than normal and their poorer speech understanding in noise is due to inability to efficiently utilize audible speech cues (Turner, Fabry, Barrett, & Horwitz, 1992). Prabhu, Avilala and Barman (2010) studied the speech perception on individuals with auditory dys-synchrony and found that speech understanding scores was poorer for low pass filtered words when compared to unfiltered words. They recommended the use of low pass filtered words while assessing the speech understanding abilities of individuals with auditory dys-synchrony. Prabhu, Vijay and Barman (2011) reported that individuals with auditory dys-synchrony having raising configuration of hearing loss got steep reduction in speech identification scores when low pass cutoff filtered words were used than using high pass filtered speech stimuli.

Speech perception in different types of hearing loss.

Speech perception ability is different for different types of hearing loss. In conductive hearing loss, the effect of attenuating sounds and reducing effective levels are observed but it does not produce any substantial changes in perception of speech sounds which are presented at level well above threshold. Hence, comparison of performance of speech understanding between conductive and cochlea hearing loss of same degree can provide some insight into the role of suprathreshold factors in cochlea hearing loss. At low stimulus level, individuals of conductive hearing loss has poorer speech understanding ability in quiet than individuals of cochlea hearing loss; but, at high level the reverse is noticed. In the presence of noise, individuals of cochlear hearing loss perform poorer speech understanding ability than conductive hearing loss even at low stimulus levels (Gatehouse & Haggard, 1987).

Boothroyd (1968) studied to determine the speech understanding ability under different low and high pass filtering conditions. The relative contribution of different frequency regions to phoneme identification for children with different configuration of hearing loss was studied. Results showed that for individuals with flat hearing losses, the contribution of speech information was reduced across all the frequencies equally, whereas for individuals with high frequency hearing loss the contribution of speech information was reduced primarily in the high frequency region. Hence, presence of hearing loss resulted in the reduction of contribution of a frequency region to speech understanding abilities, regardless of the frequency region where the hearing loss was present.

Kumar and Yathiraj (2009) also studied perception of filtered speech on simulated different configuration of hearing loss which includes gradually falling, sharply falling, rising and flat configuration. 30 normal hearing individuals participated in the study. Phonemically balanced monosyllabic words were used as stimulus. It was found that voicing errors was seen in raising configuration; in gradually sloping configuration both voicing and manner error were seen and no such error was found in steeply sloping configuration. This would be the reason of acoustic characteristic of different speech sounds which depend on the cues available in the different frequency regions. Results also showed that number of errors was more for stop sounds in rising configuration; in gradually falling configuration, fricatives and affricates error were more and more nasal errors found in sharply falling configuration.

Hornsby, Johnson and Picou (2011) investigated the effects of configuration of hearing loss on the use of and benefit from information in amplified high and low frequency speech presented in background noise. Speech understanding ability was assessed in many low and high pass filters as well as band pass and wideband condition. Results showed that individuals with steeply sloping high frequency hearing loss got better use of low pass filtered speech information than individuals with low frequency hearing loss; individuals with flat hearing loss got more benefit from extending high frequency bandwidth than individuals with slopping loss.

Speech is highly redundant owing to the simultaneous transmission of the information in several ways (Martin, 1994). Thus, many individuals of cochlear hearing loss with different configuration do not reported reduced word identification scores when speech identification test is assessed with regular monosyllabic word lists. Hence, a hearing loss involving a limited part of the frequency range may not be detected in a speech test which is not carefully controlled. This would be very evident in case of individuals with raising low frequency hearing loss. So, using regular stimulus for speech identification test may be insensitive towards identification of the problem of a person who has low frequency hearing loss.

Speech perception in low frequency hearing loss.

Low frequency hearing loss is defined as a hearing loss most pronounced for the frequency range below 2 kHz and 20 dB or more (Harper, 2006). Low frequency hearing loss is hereditary or genetic in origin. Heterozygous mutations in the WFS1 gene are responsible for autosomal dominant low frequency hearing loss at DFNA6/14 locus (Cryns & Thys, 2002). An inherited low frequency sensorineural hearing loss is reported to be due to otosclerotic changes in the cochlea (Kelemen & Linthicum, 1969; Schucknecht & Kirchner, 1974). Several conditions that affect the integrity of hair cells in the apex of the cochlea like Meniere’s disease (Opheim & Flottrop, 1957), viral infections (Djupseland, Flottorp, Degre, & Stien, 1979), sudden hearing loss, renal failure, poor cochlea development and congenital cholesteatoma are mainly associated with low frequency hearing loss. Many studies on prevalence of different configuration of hearing loss have been done. Rabinowitz, Slade, Galusha, Dixon and Cullen (2006), reported out of 2526 young adults, 16% had high frequency hearing loss and 5% had low frequency hearing loss. Further, Margolis and Saly (2008) reported a US based study which analyzed the database of academic health center audiology clinic. Results showed that prevalence of sloping hearing loss was 40%, which was followed by flat hearing loss of 16% and rising hearing loss of 3% which was the less common. Hence, on studying the prevalence of low frequency hearing loss it is observed that occurrence of low frequency hearing loss is less compared to high frequency hearing loss.

According to Berke (2011), low frequency hearing loss is not easily identified because it shows relatively symptom free. An individual with moderate degree of low frequency hearing loss will not exhibit any signs of hearing loss. One reason of why low frequency hearing loss does not exhibit signs of hearing loss is low frequency information may also carried by the high frequency fibers through temporal coding. Besides, low frequency sounds do not have much information as in the high frequency sounds and individuals with hearing in the middle and high frequencies usually make up for the sounds which are in the lower frequencies. Although they do not exhibit much problem, they still have problems in difficulties understanding speech in groups or in noisy environments (Berke, 2011).

Rosenthal, Lang and Levitt (1975) studied to determine the relative contribution to consonant reception of auditory cues contained in the low frequencies of the speech signal. A split band technique was used where the low frequency band (LB) was added to high frequency band (HB). Three low frequency bands, 55-110 Hz, 110-220 Hz and 220-440 Hz were used. Two listening modes, monotic and dichotic were used. They showed each of the low frequency bands improved the articulation score significantly when added on the high frequency band. The improvement was greatest for the highest of the three low frequency bands and smallest for the lowest band since the contribution to intelligibility per unit bandwidth is less for the lowest frequency band than for the next highest frequency band. Simultaneous presentation of HB and LB decreases the percent of error for all sound types except glides /w/, /r/ and /j/, greatest improvement seen for nasals and substantial improvement in the perception of voiceless, plosives, voiced plosives and lateral sounds.

Thornton and Abbas (1980) studied to determine whether low frequency stimuli were being detected by low frequency or high frequency nerve fibers and also speech discrimination under conditions of filtering and masking selected to contribute information on the perception of speech encoded by high frequency nerve fibers. Four individuals of moderate low frequency sensorineural hearing loss participated in the study. Psychophysical tuning curve and masking of a variable frequency probe by a high level, fixed frequency, and pure tone masker were used. A low pass cutoff of 1500 Hz and high pass cutoff of 3000 Hz were employed. Speech discrimination performance under all conditions of filtering and masking were compared. Low pass scores for individuals of low frequency hearing loss were greatly diminished when low pass filtered at 1500 Hz was used and addition of high frequency noise further decreases the scores. Results interpreted evidenced that low frequency signals near threshold were being detected by high frequency fibers in three of the subjects and small contribution of high frequency fibers to the perception of low frequency speech.

Tasell and Turner (1984) studied speech recognition on person with low frequency dead region which diagnosed on the basis of PTCs with upward shifted tips. Different speech materials like monosyllabic words, sentences and nonsense syllables were used. Two conditions which are unfiltered and low pass cutoff frequency of 1000 Hz were used for all the stimulus materials. For unfiltered conditions they reported that all the individuals performed very well in speech recognition task which were close to 100% score when speech stimuli presented at moderate level, whereas, when speech stimuli were low pass filtered, the performance of all hearing impaired individuals fell below that of normal individuals. When score of filtered sentence stimuli was compared with filtered monosyllabic words, the scores of filtered sentences was much higher than monosyllabic condition and it reflects the increased amount of linguistic and contextual information which are available in sentences.

Halpin, Thornton and Hasso (1994) measured word recognition on 14 individuals with low frequency hearing loss. CID W-22 wordlists were used and measured speech recognition scores. They reported that speech recognition scores were lower (10% to 88%) for the individuals with dead region than group without dead region (84% to 100%). They concluded that for broadband speech, subjects with low frequency dead region extracted little or no information from low frequency components in the speech.

Turner and Brus (2001) studied the benefits of low frequency speech audibility for listeners with sensorineural hearing loss in that frequency region. Eighteen subjects participated in the study and majority of the subjects had pure tone thresholds poorer than 20 dBHL for the frequencies of 1000Hz and below. Six consonant vowel (CV) lists and six vowel consonant (VC) speech materials were used. The vowels were /u/, /i/, /a/ and consonants phonemes were /b/, /t/, /d/, /ʒ/, /z/, /f/, /g/, /k/, /l/, /m/, /h/, /n/, /p/, /r/, /ʃ/, /v/, /w/, /y/, /ϴ/ and /ð/. Speech materials were low pass filtered with cutoff frequencies of 560, 700, 900, 1120, 1400, 2250 or 2800 Hz. Speech intelligibility index (SII) were used to quantify the audible speech information available to each subjects for different filter settings. They got hearing impaired listeners performed more poorly than the individuals with normal hearing for equivalent degrees of audible speech information. When speech information at 2800 Hz and below were used, efficiency values for the hearing impaired were less than 1.0, indicating they did not receive benefit from audible speech and also participants who had more severe hearing loss performed poorer than lesser amount of hearing loss in terms of perception of place of articulation.

Kumar and Yathiraj (2009) assessed the perception of filtered speech, which simulated different configurations of hearing loss (gradually falling, sharply falling, rising and flat configuration) in normal hearing individuals. 30 normal individuals, 16 females and 14 males were participated in the study. Four phonemically balanced monosyllabic word lists, each having 25 words were used. Three lists were acoustically modified to represent different audiogram configurations (gradually falling, sharply falling, rising). It was observed that in rising configuration, voicing errors were the maximum. Errors were more evident among fricatives followed by stops. It was also noted that the voicing bars that are predominant in the lower frequencies were eliminated in the rising configuration condition.

Avilala, Prabhu and Barman (2010) studied the effect of filtered speech on the perception of speech in young Kannada speaking normal hearing adults. 30 young adults participated in the study. Phonemically balanced words developed by Yathiraj and Vijayalakshmi (2005) were used to obtain speech identification scores. Low pass cutoff frequencies of 800, 1200, 1500 and 1700 Hz; High pass cut off frequencies of 1700, 2100, 2500 and 3000 Hz were used. They reported that spectral information between 1200Hz and 2100 Hz is important for perception of speech in Kannada by adults with normal hearing individuals. They further reported the discrepancy in scores between low pass cut off frequency of 1200 Hz in Kannada with 1500 Hz in English which could be due to the predominance of low frequency information in Kannada language.

Prabhu, Avilala and Barman (2011) studied speech perception abilities for spectrally modified speech signals in individuals with auditory dys-synchrony. Phonemically balanced word lists were used for spectral modification to determine the speech identification scores. The word lists were filtered at a low pass cutoff frequency of 1700 Hz and high pass cutoff frequency of 1700 Hz. 30 individuals with adult normal hearing individuals and 12 individuals with acquired auditory dys-synchrony participated in the study. Speech identification scores were determined and all the participants received three trials (unfiltered, 1700 Hz low pass and 1700 Hz high pass filtered) to each ear. It was reported that in individuals with auditory dys-synchrony, scores for 1700Hz high pass filtered words were similar to scores for unfiltered words; but, steep reduction in scores were obtained for 1700 Hz low pass cutoff filtered words. The reduced speech identification scores in auditory dys-synchrony individuals could be attributed to poor frequency discrimination abilities (Zeng, kong, Michaleski, & Starr, 2005; Rance, 2005).

Speech perception by low frequency hearing loss in the presence of noise.

Benjamin and Todd (2006) compared speech understanding of persons with hearing impaired to normal hearing individuals to examine how hearing loss affects the contribution of speech information in various frequency regions. 18 individuals with normal hearing and nine individuals with flat, moderate to severe SNHL participated in the study. Sentence recognition in noise were administered at various filter cutoff frequencies: low pass 1600 - 3150 Hz, high pass 1600 and 800 Hz and band pass 800 - 3150 Hz. Sentence recognition in noise was administered using connected speech as the test materials which consists 28 pairs of passages. Results showed that average sentence recognition scores were significantly poorer in hearing impaired groups than normal hearing individuals due to reducing audibility of the speech materials.

Jin and Nelson (2006) examined the perception of interrupted speech for normal hearing and hearing impaired listeners to investigate how well hearing impaired listener are able to in integrate fragments of speech without any possibility of forward masking and perception of speech interrupted by noise and by silent gaps. Nine individuals with sensorineural hearing loss who had thresholds greater than 20 dB but not more than 70 dB HL between 250 and 4000Hz participated in the study. Interrupted speech, speech interrupted by silence was used as stimulus. Blocks of 10 sentences were presented with each block containing one sentence spoken by each talker. Listeners with greatest hearing loss in the low frequencies were poorest at understanding interrupted sentences. Qin and Oxenham (2003) reported that, low frequency information within speech plays important role in the perceptual segregation of speech from competing background noise. Peters, Moore and Baer (1998) and Mackersie, Prida and Stiles (2001) reported that, hearing impaired individuals have reduced ability to use both spectral and temporal gaps in the background noise because of deficits in frequency selectivity and reduced audibility associated with hearing loss.

Role of speech test in hearing aid selection of low frequency hearing loss.

Vinay and Moore (2007) studied the ability of subjects with low frequency dead region to use information from frequency components of the speech falling within the dead region. 28 subjects with hearing loss at low frequencies 500, 750 and 1000 Hz of 40 dB or more were used. Individuals without low frequency dead region had thresholds of 70 dB or less whereas 70 dB or more in case of individuals with dead region. Vowel consonant vowel (VCV) nonsense syllables were used and speech intelligibility was measured. For individuals without dead regions, scores were high (78%) for low cutoff frequencies and constant up to 862 Hz and then worsened with increasing cutoff frequency. Whereas, for subjects with dead regions, performance was poor for lowest cutoff (100Hz) and improved as the cutoff increases and worsened with further increases. The study has implications for the fitting of hearing aids for people with low frequency dead regions.

Factors affecting speech Identification Test.

Familiarization.

Familiarization of the test material is very important to control for the effects of prior knowledge of test vocabulary on the speech recognition threshold (Tillman & Jerger, 1959). According to Nissen, Harris, Jennings, Eggett and Buck (2005), familiarity is one of the important factors to consider while choosing stimulus since it helps ensure the validity of the test. If the word within a list is not familiar, having difficulty understanding or responding to words, then that word should be eliminated from the list. If a word is familiar to an individual then the word is more intelligible (Elmer & Owen, 1961) and unfamiliar words tend to be more difficult to identify (Carhart, 1965). The main purpose of familiarity is to ensure that an individual knows the test materials and recognize the words auditorily so that clinician can easily interpret the response (ASHA, 1988).

Recorded vs. Live voice.

Either recorded or live can be used for speech audiometry. Recorded presentation is more preferred since it remains constant to each individual tested and better controls of the intensity of the test items (Carhart, 1965; Tillman & Olsen 1973). Recorded words are more reliable than live words as greater variability is involved in live voice (Brandy, 1966). According to ASHA, 1988, Recorded word is more preferred because it is more standardized and reduces intra- inter test variability as well as control the uniform intensity of the words presented. In recording voice, there are several advantages over tape recordings; some are increased channel separation, improved signal to noise ratio, reduced harmonic distortion and longer storage life without degradation. But, the use of recorded speech materials limits flexibility of the test procedure and produces some mechanical noise also. Hence, using live voice gives greater flexibility and also reduces the time taken for testing. Flexibility due to live voice allows the tester to fit the test to the need of the patient. Kreul, Bell and Nixon (1969) compared recorded and live voice material but got no significant difference in scores between these two materials.

Male versus Female presentation.

The performance intensity function for male and female voice presentation are different when same material is used (Wilson, Preece, & Thornton, 1990). Further, it was reported that even though male and female voice are recorded in 0 VU, intensity of the female voice had to be raise 10 -13 dB in quiet and 12-16 dB in noisy situation to obtain same performance intensity function with the male voice presentation. This discrepancy is also observed for testing word identification scores when male and female presentation of same materials of same dBHL. Hence, it is recommended that word identification scores should be obtained at specific level for male and female voice presentation.

Using carrier phrase for testing.

Carrier phrase is the instruction which precedes the stimulus words during speech audiometry. It also helped in monitoring the VU meter and helped in presenting stimulus at proper intensity level. It is mainly designed to prepare the patient for the test. Carhart (1952) used carrier phrase in speech audiometry with the intention of alerting the listener for the test word but the exact content of the carrier phrase was not given much consideration. Fletcher and Steinberg (1929) reported that CVC word recognition was greater with carrier phrase than without carrier phrase. Gladstone and Siegenthaler (1971) studied on usefulness of carrier phrase and reported that participants got poorer score for suprathreshold word recognition test without carrier phrase than those with carrier phrase. Hence, it is recommended that audiologist should use carrier phrase when obtaining word identification scores. But, according to Martin, Hawkins and Bailey (1962), carrier phrase only confused the listener who had severe discrimination problem.

Level of presentation.

Clinically, many Audiologist use SRT as a reference for speech identification testing. According to Martin and Slides (1985), most comfortable loudness (MCL) is the level used for speech identification test next to SRT. The minimum level where we get the maximum score varies across different individuals of different degree and configuration of hearing loss (Speaks, Jerger, & Trammell, 1970; Olsen & Matkin 1991). If the level of presentation is too loud, then we will reduce to a more comfortable level.

Influence of mother tongue and non-native language.

Speech audiometry can be influenced by the linguistic barrier. Hudgins, Hawkins, Karlin and Stevens (1947) reported that speech testing materials should be in a patient's own language and dialect and individual's perception of speech is influenced by his own mother tongue. According to De (1973) people consistently had better and optimum discrimination scores in their mother tongue than other language. Performance of non-native speakers was found to be consistently below than of native speakers (Ramkissoon, Proctor, Lansing, & Bilger, 2002). Perception of speech is also influenced by their mother tongue (Singh & Black, 1966). Hence, administering speech identification test in one's native language is important.

Configuration of hearing loss

Using regular stimulus for speech identification would be insensitive for testing with individuals of different configuration of hearing loss. Pascoe (1975) compared high frequency lists with regular phonetically balanced word list in high frequency hearing impaired individuals. Results revealed that high frequency word lists were more sensitive in detecting the communication deficits in high frequency hearing impaired individuals. Hence, administering speech identification test using specific word list especially for different configuration of hearing loss is very essential.

Full list vs. Partial list.

Generally, full list of 50 words should be used for speech identification testing. The reason would be some of the word scrambling has disproportionate number of sound grouping like fricatives within the certain parts of the full list. Using lesser number of words does not give true PB representation. As the number of words in a list is reduced, variability also increased (Penrod, 1994). Since full list takes time to administer, half list is also prepared. Vandana (1998) showed that there was no significant difference in the speech identification score between full and half lists.

Conclusion can be drawn from the available literature that the perception of speech might vary with change in the configuration of hearing loss. Hence, use of frequency specific test material would be sensitive to portrait an individual’s speech perceptual abilities in the presence of various configuration of hearing losses.

Chapter 3

Method

The study aimed at developing low frequency monosyllabic word list in Manipuri language for administering speech identification test. To achieve the aim the study was conducted into two phases:

1) Development of low frequency word lists and
2) Administering the developed test materials on individuals with normal hearing

Inclusion criteria for the participants.

- All the participants had normal hearing thresholds within 15 dB at octave frequencies 250 Hz to 8 kHz.
- They were native Manipuri speakers within the age range of 18 to 35 years (mean age = 23.86).
- All the participants had 'A' type tympanogram with bilateral acoustic reflex present.
- They had no history of neurological or motor problems.

Prior to their participation in the study, written consent was obtained from all the participants.

Equipments.

Audiometer.

A calibrated dual channel diagnostic audiometer, MAICO 53 calibrated as per ANSI S3.6 (1996) coupled with headphones, Sennheiser HD-200 was used for assessing PTA and speech identification test. A radio ear B-71 bone vibrator was used to estimate bone conduction thresholds.

Tympanometer.

A calibrated GSI Tympstar middle ear analyzer was used to obtain tympanogram and middle ear reflex thresholds.

Computer.

The recorded words were played using MATLAB software R2009b. The signal was routed through personal computer to the audiometer and presented those words through headphones, Sennheiser HD - 200.

Speech Materials used.

Two lists of 20 words each, which were constructed in the study, were used to obtain speech identification score for all the individuals participated in the study.

Test Environment.

Evaluations were carried out in an air-conditioned, well illuminated and acoustically treated two - room situation as per ANSI S3.1 (1999).

Test Procedure.

Routine Audiological evaluation was carried out for all the participants. Evaluations were carried out in an air-conditioned, well illuminated and acoustically treated two-room situation as per ANSI S3.1 (1999). A calibrated dual channel diagnostic audiometer, MAICO 53 was used to carry out pure tone and speech audiometer. The developed speech materials were presented through MATLAB software R2009b. The speech material was routed through a personal computer connected to the auxiliary input of the calibrated audiometer.

The speech materials developed were used to find out SI scores at +40 dB SL (ref: PTA). SI scores were obtained by using the two developed lists for both right and left ears on 30 individuals with normal hearing who were native speakers of Manipuri language. The participants were asked to follow the instructions and respond by ‘verbal repetition’.

Chapter 4

Results and Discussion

The aim of the present study was to develop low frequency monosyllabic word list for speech identification test in Manipuri language and to obtain the scores on individuals with normal hearing sensitivity. The results of the present study is discussed under the following two phases 1) Development of low frequency word lists and 2) Administering the developed test materials on individuals with normal hearing.

4.1 Development of low frequency word lists

This phase includes four stages a) Collection of various monosyllabic low frequency words and their familiarity rating assessment b) Recording and selecting the best recorded words c) Grouping of the words having low frequencies spectrum and d) Generating equally difficult word groups.

4.1.1 Collection of various monosyllabic low frequency words and their familiarity rating assessment.

Familiarity becomes an important factor while assessing speech recognition abilities of native speakers. Hence, monosyllabic words with phonemes /m/, /n/, /l/, /y/, /o/, /u/, /w/, /ɳ/, /a/, /r/, /d/ were chosen since these phonemes have energy at low frequency. Monosyllabic words, a total of 221 words were collected. Further, the collected words were given to 10 Manipuri native speakers to rate for the word familiarity by using a 3 point rating scale i.e., most familiar, familiar and less familiar. 194 words were left out and these words were taken for construction of the word lists.

4.1.2 Recording and selecting the best recorded words.

With the help of a male speaker having normal voice with clear articulation, the selected words were recorded using Computerized Speech Lab-Model 4500. To select the best recorded words, both subjective and objective analysis were done for the selection of recorded words. Subjective analysis was done based on voice quality, clarity, intonation, naturalness and presence of any audible background noise. Whereas, objective analysis was done using Pratt software (version 5.3.53). Words having clear pitch and formants from the objective analysis were considered.

4.1.3 Grouping of the words having low frequencies spectrum.

Fast Fourier Transform (FFT) was performed by using MATLAB software. 1.5 kHz was taken to be the cutoff frequency to determine if the words collected were in low or in high frequency spectrum (Berger, 2003). The ratios of the energy amplitude below and above 1.5 kHz were obtained for all the words. Further, k-means clustering (k=2) was performed based on their amplitude ratios to group them into high and low frequency clusters. Words having amplitude ratio > 1.45 were considered for making the word lists and hence, a total of 98 words were left out. Further, using MATLAB, long term average speech spectrum (LTASS) was obtained for the low frequency words which are remaining to verify the correct categorization of words into low frequency words.

4.1.4 Generating equally difficult word groups.

Speech identification scores (SI scores) were obtained using the low frequency words to 3 different adult Manipuri speakers with normal hearing at different sensation levels (SL; ref: PTA) +0, +4, +8 and +16 dBSL . The scores obtained from the subjects at each SL were averaged. Based on these average scores, psychometric functions were derived for all the words. The mean sensation levels where 50% scores occurred and mean slope of the psychometric functions were obtained. Words falling within ±1.5 standard deviation to the mean and slope were considered for making the word lists. A total of 40 words remained and two lists of 20 words which are in equal difficulty level were made.

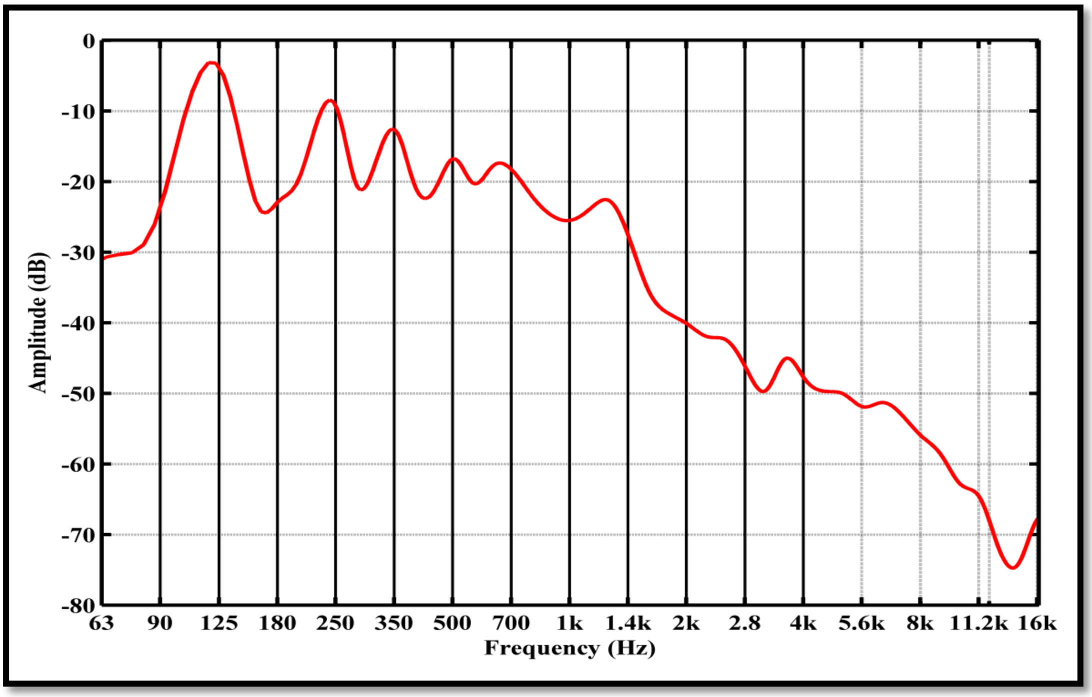

Figure 4.1 LTASS for cluster of low frequency words.

The Figure 4.1 shown above indicates the LTASS results. From the Figure, it is clearly evident the energy difference between high and low frequency region and all the 40 words has predominant spectral information in the frequency region below 1.5 kHz.

4.2 Administering the developed test materials on individuals with normal hearing.

Using the developed low frequency word lists of 20 words each, speech identification scores for 30 Manipuri individuals with normal hearing were obtained. The speech identification test was assessed for both right and left ears and each ear received both the lists. Descriptive statistics was carried out using Statistical Package for Social Sciences (SPSS) version 17.0.

The following statistical procedures were used to explain the results mentioned below.

- Descriptive statistics to find the Mean and standard deviation of SI scores for both ears across the two lists.
- Two way repeated measure ANOVA for comparison of SI scores obtained under the following state of affairs:
  a) Comparison of SI scores between the ears.
  b) Comparison of SI scores between the lists.
  c) Comparison between lists and ear interaction.

4.2.1 Mean and standard deviation of SI scores for both ears across the two lists.

The mean and standard deviation of low frequency speech identification scores for 30 individuals were obtained. This was done for both ears across the two lists (Table 4.2).

Table no 4.2 Mean and standard deviation (SD) of SI scores of individuals with normal hearing

Lists	***Ears***	***Mean***	***Mean (%)****	***SD***
List 1	Right	18.60	93.0	1.00
	Left	18.53	92.6	1.00
List 2	Right	18.26	91.3	1.22
	Left	18.40	92.0	1.30

* Indicates the converted mean (%) from the mean scores.

The speech identification scores obtained for both right and left ear for the two lists are given separately in the above table. As can be seen from the table, there is only a little difference between the mean and standard deviation for both the ears across the two lists and slight reduction in speech identification scores. The result are in agreement with Prabhu, Avilala and Barman (2011); Tesell and Turner (1984); they also obtained a slight reduction in speech identification scores of 90% and 96% respectively when filtered low pass speech stimuli was used.

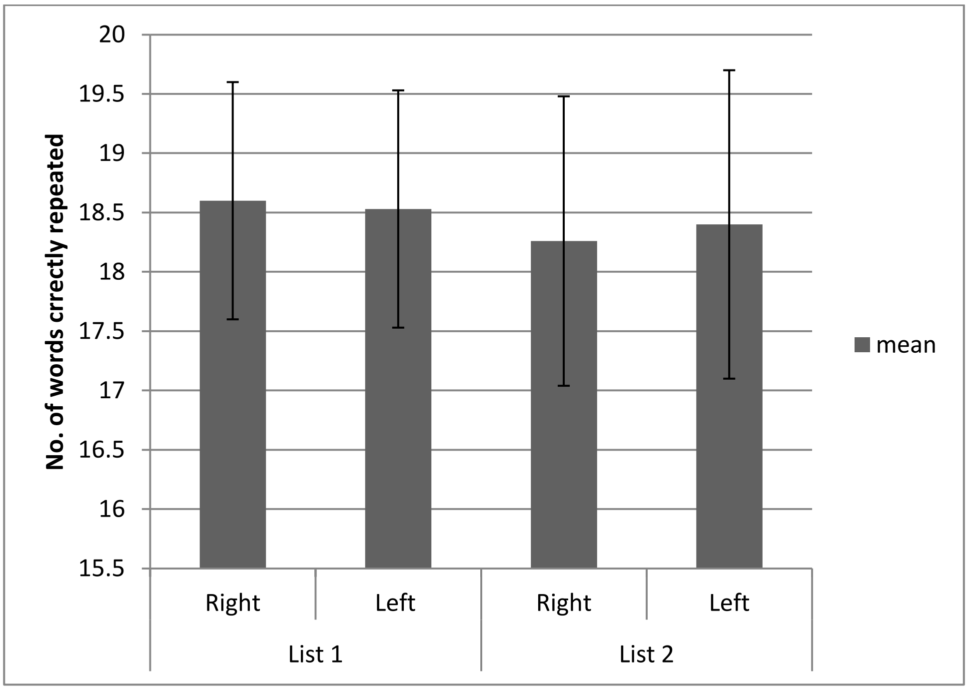

Figure 4.2 Mean speech identification scores and SD of 30 individuals with normal hearing plotted for both ears across the two lists

4.2.2 Comparison of the speech identification scores between the ears.

Speech identification scores between the ears were compared. Results revealed that there was no significant difference in the speech identification scores between the ears [F (1, 29) = 0.969, $p > 0.05$]. Hence, Speech identification scores between the ears had similar results with good equality and any of the lists can be used interchangeably for right and left ear.

4.2.3 Comparison of the speech identification scores between the two lists

One of the considerations during development of any speech materials is that the alternative form of a test should be equivalent; that is they should produce comparable results (Gelfand, 2009). Hence, to check the equality, the speech identification scores were compared across the two lists for both ears separately. The results showed that there is no significant difference in the speech identification scores across the two lists [$F (1, 29) = 0.037$, $p > 0.05$]. Hence, it can be said that the speech identification scores obtained from the two lists yield similar results and have good equality with not much difference in terms of redundancy between the two lists. Thus, either of the lists can be used for testing low frequency speech identification test. Since the two lists yield good equality without much difference, a third randomization list also can be made from the available two lists, if required.

4.2.4 Comparison between lists and ear interaction

The interaction between the lists and ear were also checked. Results revealed there is no significant interaction between the lists and ear [$F (1, 29) = 0.332$, $p > 0.05$). Hence, it is observed that the two lists which have been developed in the present study are not ear specific which implies that the speech materials developed are applicable for using in speech identification test either for right or left ear.

Chapter 5

Summary and Conclusion

Individual with hearing loss have difficulty in perception of speech sounds and the kind and extend of perceptual difficulties depends on many factors like degree of hearing loss, type of hearing loss and audiogram configuration (Gardner, 1971; Jerger & Jerger, 1971; Pascoe, 1975; Owens & Schubert, 1977). Hence, an individual with low frequency hearing loss would have difficulty in perceiving low frequency sounds (McDermott & Dean, 2000). According to Pascoe (1975), hearing loss involving limited region of frequency range may go undetected in speech test when the speech stimuli used for speech audiometry is not carefully controlled. Using regular speech materials would be insensitive while assessing and rehabilitating of individuals having low frequency hearing loss as configuration of hearing loss will have an effect on speech perception. With this, the present study aims at developing low frequency word list in Manipuri language for administering speech identification test.

The study was conducted in two phases. In the first phase, two low frequency word lists were developed in Manipuri language. This was done by collecting 221 words from different sources. Further, these 221 words were used for familiarity rating using a three point rating scale and 194 words were selected from this corpus. FFT was done by using MATLAB software R2009b for the remaining words to determine if the words selected were in low or high frequency spectrum and 1.5 kHz was taken to be the cutoff frequency. Later, k-means clustering was performed based on the amplitude ratios of words above and below 1.5 kHz and words having amplitude ratio > 1.45 were considered for making the list. Hence, a total of 98 words remained. LTASS was also performed to determine the remaining words are having low frequency spectrum. Later, for generating equally difficult word in the corpus, speech identification scores were obtained for all the remaining words at different sensation levels (SL; ref: PTA) +0, +4, +8 and +16 dBSL. Scores obtained from each sensation level were averaged. Based on the average scores, psychometric function was derived. From the psychometric function, the words were selected based on two criteria 1) The mean sensation levels where the individuals got 50% scores and 2) The slope of the psychometric function. Words falling within ±1.5 standard deviation to the mean and slope were considered and a total of 40 words remained. For constructing equalized list, firstly 20 words were randomly selected from the available word pool of 40 words. For each list, mean SL where 50% scores occurred and mean slope was found out. This mean SL and slope were compared with the mean SL and slope of the low frequency word pool obtained initially. If the mean value was within ±1.5 standard deviation, then the list considered was selected. If not, then another set of 20 words were randomly selected and this procedure was repeated. As a result, finally two word lists of 20 words each were formed.

In the second phase, using the developed two lists, speech identification (SI) scores were obtained on 30 normal hearing individuals for both ears across the two lists.

The data was analyzed using SPSS (version 17.0) and results were described under following headings:

a) Mean and standard deviation of SI scores for both ears across the two lists.
b) Comparison of SI scores between the ears.
c) Comparison of SI scores between the lists.
d) Comparison between lists and ear interaction.

The following are the conclusions made from the results obtained.

a) Mean and standard deviation of SI scores for both ears across the two lists.

There is little difference between the mean and standard deviation in the scores obtained for both the ears across the two lists. It can be conclude that the developed lists are likely to give similar scores when used in clinical conditions.

b) Comparison of SI scores between the ears.

Results showed that there is no significant difference in the speech identification scores between the ears. Hence, the two lists can be used irrespective of the ear.

c) Comparison of SI scores between the lists.

Comparison of SI across the lists showed that there is no significant difference in the speech identification scores across the two lists. Therefore, either of the lists can be used for low frequency speech identification test.

d) Comparison between lists and ear interaction.

Results showed that there is no significant ear interaction using both the lists. Therefore, both the lists can be used for testing speech identification irrespective of the ear being tested.

Utility of the developed test material.

1. The low frequency speech identification test can be utilized for assessing the perceptual difficulties of individuals with low frequency hearing loss who are native speakers of Manipuri language.
2. These word lists can also be used for selecting appropriate hearing aid device for individuals with low frequency hearing loss.

Future research directions.

1. The developed lists need to be administered on individuals with low frequency hearing loss to check for the efficiency in clinical population.
2. The speech materials can be standardized by administering the speech identification test on more number of individuals.
3. The developed lists can be used to evaluate the speech identification performance with low frequency hearing loss, using various types of hearing aids.

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Appendix

Low Frequency Word List for Speech Identification Test in Manipuri Language for Adults.

Rojina D. N. & Sreeraj K., 2014

List 1	List 2
/ləm/	/loːi/
/koːn/	/kuː/
/kəŋ/	/huː/
/lao/	/laːn/
/bən/	/kʰaː/
/bor/	/aːin/
/ləŋ/	/loi/
/haːr/	/baːp/
/gjaːn/	/laː/
/hiŋ/	/hək/
/d̪ao/	/kʰoːŋ/
/caːŋ/	/baː/
/kʰaːŋ/	/d̪aːk/
/kaː/	/d̪uːp/
/lən/	/ha/
/hao/	/loːk/
/hoi/	/kʰon/
/kʰəu/	/kəŋ/
/leːŋ/	/len/
/hoːi/	/kʰun/