MIZO HIGH FREQUENCY SPEECH IDENTIFICATION TEST (MHF-SIT)

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CERTIFICATE

This is to certify that this dissertation entitled ***"Mizo High Frequency Speech Identification Test (MHF-SIT)"*** is a bonafide work in part fulfillment for the degree of Master of Sciences (Audiology) of the student (Registration No. 10AUD016). 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.

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DECLARATION

This dissertation entitled ***"Mizo High Frequency Speech Identification Test (MHF-SIT)"*** is the result of my own study under the guidance of Mrs. Chandni Jain, Lecturer in Audiology, Department of Audiology, All India Institute of Speech and Hearing, Mysore, and has not been submitted earlier to any other University for the award of any other Diploma or Degree.

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Dedicated to My Father & Mother

And to the people of Mizoram

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CHAPTER I

INTRODUCTION

Hearing is the ability to perceive sounds by detecting vibrations through the organs of hearing. The basic mechanism for speech perception and effective communication precludes the ability to hear speech accurately. Speech perception involves the process by which the sounds of language are heard, interpreted and understood.The speech signal contains a number of acoustic cues like voice onset time, place of articulation or manner of articulation that are used in speech perception.These acoustic cues and other phonetic information are used for higher language processing and word recognition.An individual needs good hearing ability in order to decode a message from a stream of sounds coming from a speaker for effective communication (Borden & Harris, 1980) and it is a known fact that a person with hearing loss will have communication problem.

In acoustic terms, vowels and consonants are described by their average pitch (frequency, measured in Hertz – Hz) and their average loudness (intensity, measured in decibels – dB) at conversational speech level. The conversational speech has the most acoustic energy between 500 Hz and 3000 Hz. This frequency region is important for understanding meaningful speech (Pavlovic, 1987; Studebaker & Sherbecoe, 2002). A person needs to hear upto 1000Hz in order to hear all the vowels, but he/she needs to hear upto 3000 Hz inorder to discriminate between the vowels and this helps us to discriminate between words that otherwise sounds same. However, the speech energy above 3000 Hz is also reported to offer listeners important linguistic information. Thus, one needs to have normal hearing sensitivity at high frequencies for good speech recognition. Any pathology that reduces hearing sensitivity at high frequencies will also affect speech recognition.Therefore, it is the essential duty of audiologists to identify, evaluate and rehabilitate aurally handicapped individuals.

An individual's hearing can be evaluated through the presentation of sounds (tones) or speech. This evaluation involves administration of different audiological tests which assess the degree, type and configuration of hearing loss. Audiological evaluations also intend to provide information that describes the functional impact of hearing loss on communication.

Pure tone audiometry is a hearing test that involves presentation of a series of sinusoidal tones (or beeps), to the listener, at specific frequencies to establish a person's hearing acuity. However, pure tone audiometry can only assess the auditory system's ability to "carry a simple stimulus" (Egan, 1979), and provides little information about the individual's ability to understand speech; speech audiometry is a type of audiological evaluation designed to better describe communication abilities and attempts to indicate how an individual may hear and understand spoken discourse by presenting words, instead of tones, during testing (Epstein,1978). Also because speech is a complex and continually varying signal requiring multiple auditory discrimination skills, it is not possible to accurately predict an individual's speech recognition from the pure-tone audiogram (Marshall & Bacon, 1981).Thus, pure tone audiometry provides little information about the individual's ability to understand speech.

Speech audiometry is routinely administered by audiologists as part of their audiologic evaluation battery. Basic speech audiometric tests includes speech detection threshold (SDT), speech recognition threshold (SRT), speech identification scores (SIS), most comfortable level (MCL), and uncomfortable level (UCL). The purpose of these tests is to validate the pure tone air-conduction threshold and provide an index of hearing sensitivity for speech (Carhart, 1952; Chaiklin &Ventry, 1964). Speech audiometry materials were first developed in Standard American English but are now available in various other languages such as Hindi (Abrol, 1970; De, 1973), Spanish (Harris & Christensen, 1996), Italian (Turrini, Cutugno, Maturi, Prosser, Leoni, & Arslan,1993; Greer, 1997), Portuguese (Harris, Goffi, Pedalini, Merrill, & Gygi, 2001, Polish (Harris, Nielson, McPherson, & Skarzynski, 2004), Mandarin Chinese (Nissen, Harris, Jennings, Eggett, & Buck, 2005), Russian (Harris, Nissen, Pola, McPherson, Tavartkiladze & Eggett, 2007), Tongan (Sever, 2008), etc. However, allthese materials are conventional or regular speech audiometry materials which were developed and standardized on individuals who have mostly flat or nearly flat type of audiometric configuration. The use of these standard speech test can give prediction of the best hearing threshold levels in the mid frequency region of the auditory range.

It is also known fact that a person with hearing loss is bound to have difficulty in perceiving speech. The kind and degree of perceptual difficulty depends on several factors, which include the degree of hearing loss, the type of hearing loss and the configuration of the audiogram (Jerger & Jerger, 1971; Gardner, 1971; Pascoe, 1975; Owens & Schubert, 1977; Lacroix & Harris, 1979). Depending on the audiometric configuration the speech perception ability would vary. A person with a high frequency hearing loss would have difficulty mainly in hearing speech sounds having energy concentration in the high frequency regions (Stark, 1979; McDermontt & Dean, 2000). Martin (1987) concluded in his study by saying that speech perception would vary depending on whether the person had gradually sloping, sharply sloping or precipitously sloping audiograms. Another study by Mascarenhas (2002) also indicated that individuals with a sharply sloping high frequency hearing loss perform poorer than those with gradual and precipitous sloping high frequency hearing loss on High Frequency-Kannada Speech Identification Test (HF-KSIT).

Speech is a redundant stimuli as it contains information that is conveyed in various ways simultaneously (Martin, 1994). A hearing loss involving only part of the auditory frequency range may go undetected in a speech test if it is not carefully controlled. Thus, the use of a regular speech identification test would be insensitive towards identification of the problem of a person with a sloping high frequency hearing loss. In regular speech material, low frequency information may contribute redundant cues to the perceptual ability, thereby decreasing the sensitivity of the test in detecting their communication handicap (Sher & Owens, 1974; Schwartz & Surr, 1979; Kiukaanniemi & Maatta, 1980).

Owen & Schubert (1977) developed 100 multiple choice items for consonant identification in the California Consonant Test (CCT) to use with hearing impaired patients. A computer assisted analysis was obtained for the test responses of 550 patients with sensorineural hearing loss. They found that the test seems highly sensitive to configurations of high-tone loss, but were not sensitive to a regular speech test, i.e. CID W-22. They concluded that the two tests are measure different aspects of speech perception and the regular speech test does not assess the real communication problem of individuals with a high frequency loss. Similar results were obtained by Chung and Mack (1979),indicating that in quiet condition, both normal hearing subjects and individuals with a high frequency hearing loss performed equally on a regular speech test (i.e. CID W-22). This indicated that the test was not sensitive to the communication problems of individuals with high frequency sensorineural hearing loss.

Thus, it can be concluded that, regular speech identification tests are not sensitive to assess the perceptual problems of individuals with a sloping high frequency hearing loss. Hence, there is a need for special test to be developed and used while testing them. Such special tests have been developed in the past and they are called High Frequency Speech Identification Test. First high frequency word list was developed by Gardner in Standard American English (Gardner, 1971). The test contains consonants of high frequency spectral energy and is used for testing speech identification in cases of high frequency hearing loss. Currently, knowing its importance, these kind of tests are also developed in different Indian languages such as High frequency speech identification test in Hindi (Ramachandra, 2001), High frequency-Kannada speech identification tests (Mascarenhas, 2002), High Frequency-English Speech Identification Test (HF-ESIT) (Sudipta, 2006), High Frequency Speech Identification test in Tamil (Sinthiya, 2009), and High Frequency Speech Identification test in Telegu (Ratnakar, 2010). However, such materials are not currently available in the Mizo language. The purpose of this proposed study is therefore to develop high frequency speech identification tests materials for native speakers of Mizo.

Need for the study

Incidence of hearing disorders, particularly sensorineural hearing loss (SNHL) rapidly increases with aging, affecting nearly a third of people over 65 and one-half of those over 85 years (National Centre for Health Statistics Publication, 1986).

Numerous studies have reported loss of hearing with age, occurs particularly for sounds in the high-frequency range (Schuknecht, 1964; Marsh, 1998; Gulya, 2000) (above 2 kHz), which corresponds to more extensive pathophysiological changes in the corresponding regions of the inner ear (Liberman & Doodds, 1984; Williott, 1991). The marked hearing deficits in the high-frequency range have an important bearing on impaired speech perception in the elderly (Jerger & Hayes, 1977; Gulya, 2000).

Audiological tests such as pure tone thresholds does not allow for complete understanding of a person's communication deficit, speech identification tests are generally used to determine the degree of communicative handicap. The available speech identification tests are phonetically balanced and are standardized on individuals having flat audiometric configuration. Using these tests may not give the client's true performance of speech perception ability, particularly those individuals with sloping high frequency hearing loss due to inherent redundancy in natural speech. The spectral information present in the low frequency regions (below 2 kHz) where the hearing is normal or near normal could contribute to perception of speech by auditory closure. Hence, speech identification scores obtained for High frequency word list is a better estimate of communication handicap for such individuals, the study attempted to develop the test material. Since it was also reported that the identification scores are maximum in the individual's own native language (De, 1973), a separate list is required in Mizo language.

The Mizo language is natively spoken by Mizo people in Mizoram, state in the Indian Union; Chin State of Burma and in the Chittagong Hill Tracts of Bangladesh. The language is also known as Lushai. Mizo is a tonal language, in which differences in pitch and pitch contour can change the meanings of word. Tone systems have developed independently in many of the daughter languages largely through simplifications in the set of possible syllable-final and syllable-initial consonants.

Also, selection of profitable hearing aids for elderly people or who have sloping high frequency hearing loss depends on utilizing a test which is sensitive to their problem (Sudipta, 2006). A significant improvement in speech identification scores was reported between the aided and unaided scores when High Frequency-Kannada Speech Identification Test (HF-KSIT) was administered instead of Common Speech Identification Test (CSDTI) developed by Mayadevi (1974) in individual with high-tone loss (Mascarenhans, 2002).Thus, the use of speech identification test normally used may not determine their true communication handicap giving a maximum score unaided.It is unlikely that a person with sloping high frequency hearing loss will get maximum score unaided if a tests material is used which are specially designed for their type of hearing loss.

Objectives of the Study:

a) To develop high-frequency word list in Mizo language.
b) To establish a normative and standardize the newly developed material in normal hearing adults, who are native speakers of Mizo.
c) To check the equality of different lists that is developed.

CHAPTER II

REVIEW OF LITERATURE

2.1 Speech Audiometry

Speech communication is one of the most important characteristic features of human race (Plomp, 2002). The two components of speech communication i.e. speech perception and speech production are closely related and have been studied extensively in the past. There is a clear difference "between the threshold for speech or speech perception and the ability to understand the speech that is heard" (Gelfand, 2001). This is understood when individual with hearing impairment complaint that he/she can hear, but cannot understand speech or speech sounds muffled. With the exception of the most severe cases, hearing loss diminishes the intensity, clarity, or intelligibility of speech, and not its detection. Pure tone Audiometry provides only a partial picture of the patient's auditory sensitivity and can only make the "grossest generalizations regarding the degree of disability in speech communication" (Martin & Clark, 2009), caused by hearing loss.

Speech Audiometry is a technique that involves presenting standardized speech stimuli (usually words) through a calibrated audiometer in order to measure and qualify an individual's ability to recognize and understand speech; this process typically involves administering test materials to determine two different but related measures: speech recognition threshold (SRT) and the word recognition score (WRS).

Speech Recognition Threshold (SRT) indicates the intensity level (in dB HL) where an individual can correctly recognize 50% of the words presented (ASHA, 1988). Materials used for SRT testing are often closed set spondaic (two syllable) words with equal stress on both syllables. Closed set word lists are first shown to the listener before testing in order to familiarizing the subject with the test items (words). Speech Recognition Threshold (SRT) testing is often done before Speech identification scores (SIS) testing as the person's speech recognition threshold determines the intensity level at which SIS items are presented.

Speech Identification Scores indicates the identification ability of an individual. It is also called as Speech Recognition Scores. This test is done at supra threshold level (e.g. 30 to 40 dB above SRT) and score is calculated in terms of percentage. Thus, Speech Identification Scores refers to those tests that require the patient to attach a label to the stimulus either by pointing to a corresponding picture or object or repeating the stimulus orally or in writing (Roeser, Valente & Dunn, 2007). There are several terms associated to these tests viz. Word Recognition Score (WRS) is applied for word stimuli and Sentence Recognition Score (SRS) is applied for sentence stimuli. However, some audiologists continue to use the term Speech Discrimination Score (SDS) for all measures of identification or recognition of speech at supra-threshold levels.

Evaluation of speech processing using speech audiometry is an important component of the diagnostic audiological evaluation. Speech thresholds (e.g. SRT) provide validating data for pure tone thresholds and supra-threshold (e.g. SIS/SRS/SDS) levels tests contribute to decisions regarding site of lesion and development of rehabilitation programs.

2.2 Guidelines for the Development and Evaluation of Materials for Speech Audiometry

Over 65 years ago, Hudgins, Hawkins, Karlin & Stevens (1947) suggested several guidelines for the development and evaluation of materials for speech audiometry testing which are still useful. Subsequent developments in recording technology and psychometrics have expanded and clarified these guidelines (ASHA, 1988; Brandy, 2002).

First, the materials must be familiar to the person being tested. As the goal is testing speech intelligibility, not vocabulary or intelligence, and thus items should be as simple and familiar as possible. It was evident with unfamiliar words of PB-50 lists which showed poor inter-list reliability (Hirsh, Davis, Silverman, Reynolds, Eldert & Benson, 1952). Listening to words that are unfamiliar reduces the value of SRT measurements obtained (Ramkissoon, 2001). This guideline also suggests that materials should be in a patient's own language and dialect. Weisleder and Hodgson (1989) found that performance on SRT tasks was negatively affectedwhen listening to recordings from a talker with a different dialectal background, even within a shared language. If possible, native talkers of the intended language should be used to develop, record, and present materials.

A **second guideline** is that words should differ phonetically from each other; rhyming or phonetically similar words increase test difficulty without contributing to accuracy of assessment. Lexical characteristics of particular words in a stimulus set can exert a strong influence on overall intelligibility (Bradlow & Pisoni, 1999).Lexical items may be organized in an individual's mental lexicon according to semantic or phonologic properties, thereby creating a series of similarity neighbourhoods (Dirks, Takayanagi & Moshfegh, 2001). Phonetic dissimilarity ensures that the words do not provide additional auditory cues like those found in rhyming words (Ramkissoon, 2001).

A **third guideline** mentioned was that of a normal sampling of English speech sounds. They noted that this criterion was of lower importance and was not essential for a valid measure of hearing ability. Although historically efforts have been made to ensure that word lists used for WR were phonetically balanced (Eldert & Davis, 1951; Lehiste & Peterson, 1959). Martin & Champlin (2000) found that phonetic balance does not significantly influence WR scores for patients with normal hearing or sensorineural hearing impairment. It was found in their results that the WR score based on a randomly selected list of words was not significantly different from a score based on a list of phonetically balanced words.

The **fourth guideline** was that word stimuli need to be homogenous in regards to audibility. The audibility of a test word can be measured in terms of psychometric threshold and slope. The psychometric slope relates to the rate of correct recognition as a function of intensity, with the psychometric threshold being related to the intensity intercept of the psychometric function. As stimuli increase in homogeneity, the results of the SRT evaluation become more precise (Wilson & Carter, 2001). Likewise, low-noise recordings of native-language testing materials allow examination of the consistent psychometric properties of these materials and their presentation.

Thus, during the development of any speech material, all these factors should be kept in mind and changes can be made according to the purpose of development of speech material.

2.3 Importance of High Frequencies in Speech Intelligibility

Speech testing is usually done to see levels of communication handicap created by the hearing loss and should differentiate the normal hearing individuals from those with sensorineural hearing impairment. However, many listeners with cochlear hearing loss often do not manifest reduced word identification scores when performance is assessed with commonly used monosyllabic word lists. This is particularly evident when word recognition ability is assessed in individuals with high frequency sensorineural hearing loss (Sher & Owens, 1974).The major factors that can influence the speech identification or word recognition ability are degree of hearing loss and the configuration (slope) of hearing loss.

The acoustic information in speech is quite complex and has many dynamic variations.Speech sounds by its nature, changes over time in terms of level and spectral content. In general, speech intelligibility depends on information derived from consonants whereas vowels contribute to the power of speech (Niemeyer, 1967). It is thus crucial for a person to identify consonants properly in order to understand speech better. This requires the identification of place as well as manner of articulation which in turn are cued by dynamic filter cues like closure duration, burst and transition (Dorman, Studdert-Kennedy & Rapheal, 1977). The spectral cues for place and manner of articulation of different high frequency speech sounds are given in Table 2.1.

The table represents the spectral energy of the consonants and the major cues for the perception given by Hughes and Halle (1956). Several studies have been done in past to show the importance of high frequency in understanding speech.

Table 2.1: *The spectral energy and the major cues for perception of consonants*

Phonemes	Energy Spectrum	Place Cue	Manner Cue
/s/	2000 – 4000 Hz	Spectral properties – F2 transition, noise duration and amplitude (overall and relative amplitude)	Duration of frication noise, amplitude of noise component and fundamental frequency at vowel onset.
/ʃ/	3500 Hz		
/f/	6800 – 8400 Hz		
/k/	1500 – 4000 Hz	Frequency position of burst, F2 transition, spectral pattern, voice onset time.	Stop gap, silence, closure duration, duration of preceding vowel, F1 cutback.
/ṱ/	Above 4000 Hz		
/ʤ/	2500 Hz	Duration of noise segment. Rise time of noise segment.	Frication duration, closure duration.

Niemeryar (1967) used German sentences in random noise corresponding roughly to traffic noise and estimated that speech energy above 3 kHz offers important linguistic information. The standardised speech intelligibility index (SII-ANSI) allocates 21% of the importance of the average speech to the 1/3rd octave bands at 3150 Hz and above. It is crucial that one perceives the spectral cues in the higher frequencies for 100% speech understanding. It is logical to expect that individuals with hearing loss will have poor speech intelligibility due to reduced audibility. High frequency hearing loss (HFHL) is the most common configuration seen in individuals with sensorineural hearing loss, particularly in Presbycusis and for them, the audibility of higher-frequency consonant energy are sacrificed, often becoming inaudible. Hence, the client with this configuration of hearing loss usually presents with complaints of difficulty understanding or recognizing conversational speech. This is particularly common if speaker is talking softly or is in the presence of background noise.

Lawrence and Byers (1969) studied identification of voiceless fricatives in five male adults (aged 25 – 55 yrs) with HFHL. The stimuli used were 16 CV syllables by combining each of the fricative /ʃ, s, f, ɵ/ with four vowels /i, e, o, u/. The percentage correct identification of fricatives was /ʃ/ - 87%, /s/ - 77%, /ɵ/- 72% and /f/- 83%. The subject showed confusion for fricatives combined with front vowel /i/ and /e/, than with back vowel /u/ and /o/. Even /ʃ/ was confused for /s/ and, /f/ for /ɵ/. However, there were no vowel confusions. Although the study showed fairly good identification, the scores will probably reduce drastically in the presence of noise, due to masking of low frequency cues.

Sher and Owens (1974) reported the importance of cues above 2 kHz for extracting meaning from rather highly contextual sentences when the redundant nature of acoustic, grammatical, lexical, linguistic, and prosodic content of sentences was reduced by distortion. It was noticed that, greater the distortion, greater the higher frequencies required for maximum understanding.

Dubno, Dirks & Schaefer (1987) in their study evaluated the utility of short term spectral cue for recognition of initial plosive consonant by normal and hearing impaired listeners of different audiometric configurations. They found that hearing impaired do not perform well with short duration stimuli as they are unable to make use of the cues present with the magnitude of difference present depending on the audiometric configuration. In another study by Zeng & Turner (1990) reported that adults with sensorineural hearing loss have difficulty in using transition cues to identify voiceless fricatives than normal hearing listeners, even when the transition was clearly audible.

Horwithz, Dubno & Ahlstrom (2002) in their study attempted to determine if high-frequency hearing loss results in speech understanding deficits beyond those accounted by reduced high-frequency speech information. Their results showed that HFHL had deficit in recognition of unfiltered speech in noise compared to normal hearing listeners which was attributed to the reduction in the high frequency audibility. Listeners with impaired high frequency showed difficulty in the perception of low frequency speech in noise compared to normal hearing subjects. The high frequency hearing loss may reduce the contribution from the "tails" of high frequency auditory nerve fibres, resulting in diminished availability of lower frequency speech cues. They also reported reduction in audible high-frequency speech information and reduced frequency resolution among sensorineural hearing loss subjects.

In another study, Prawin &Yathiraj (2008) studied perception of speech by stimulating different configurations of hearing loss through phonetically balanced monosyllabic words. Error patterns were noted depending on the configuration of hearing loss. In the rising pattern voicing errors were maximal, whereas place errors were less. In gradually falling pattern, manner and place errors were evident while in sharply falling patterns only place errors were evident.Thus subjects with high frequency hearing loss have difficulty perceiving place cues. However, simulation of high frequency hearing loss may not be equivalent to the actual hearing loss.

From the above studies discussed, it can be concluded that high frequency information is important for speech intelligibility. Also, speech intelligibility depends on information derived from consonants whereas vowels contribute to the power of speech. It is crucial for a person to identify consonants properly in order to understand speech better. It was also noticed that hearing loss distorted speech perception, and greater the distortion, greater the higher frequencies required for maximum understanding.

2.4 Speech Perception in the presence of Noise

The range of frequencies which have a significant effect on word recognition in the presence of noise are those between 2500 and 6300 Hz (Pascoe, 1975). Cohen and Keith (1976) attempted to determine whether WRS obtained in quiet and in noise condition differ with the pattern of hearing loss. Subject comprised of high frequency cochlear hearing loss and flat cochlear hearing loss who were tested in quiet and in the presence of a 500 Hz low – pass noise in 2 SNR conditions (-4 dB & -12 dB). The results indicated that, WRS were similar between the two groups in quiet, but deteriorated in the presence of noise for high frequency hearing impaired participants as compared to those having flat cochlear hearing loss. Turner and Henry (2002) also found that amplified high frequency speech information improved speech understanding in noise of listeners with sloping SNHL, regardless of the degree of hearing loss.

Hornsby and Ricketts (2003) examined the contribution of speech information available in various frequency regions for speech understanding by comparing speech perception in noise between persons with flat SNHL and listeners with normal hearing. Results showed that access to high frequency information resulted in comparable improvements in speech understanding for listeners with flat SNHL and normal hearing.

Amos & Humes (2007) examined the contribution of audible high-frequency information to speech-understanding performance in listeners with varying degrees of high-frequency sensorineural hearing loss. Thirty-six elderly hearing-impaired (EHI) and 24 young normal-hearing (YNH) listeners were tested in quiet (+20 dB speech-to-noise ratio [SNR]) and noise (+5 dB SNR) and under different band-pass conditions (narrow, 200–1600 Hz; mid-band, 200–3200 Hz; broadband, 200–6400 Hz), both without and with spectral shaping of the stimuli. Monosyllabic word-recognition performance was examined through use of both whole-word scoring and phoneme scoring. Results for spectrally shaped speech, in both quiet and noise revealed that the EHI groups performed equivalently in the different bandwidth conditions and demonstrated no change (increase or decrease) in word-recognition performance between the midband and broadband conditions. The YNH groups, however, demonstrated improved speech understanding attributable to the higher frequencies for the broadband condition in both the unshaped and shaped conditions. Thus, data from the EHI listeners revealed that performance for unshaped speech was correlated moderately and negatively with degree of high-frequency hearing loss. Alternatively, recognition performance for shaped speech was related to neither the performance for unshaped speech nor the amount of high-frequency hearing loss.

From the above discussed studies, it is clear that both individuals with a high frequency hearing loss have difficulty in the perception of speech; particularly their speech perception deteriorates in the presence of noise. This is also seen in individuals with flat hearing loss.However, there is variation in the severity of the problem across individuals. Individuals with high frequency slope will need amplified high frequency information to improve speech perception.

2.5 Role of speech tests in hearing aid selection

Speech tests play important role in selection of suitable hearing aid for hearing impaired individuals. Various hearing aids can be tested in order to distinguish which provide a better intelligibility in adverse listening conditions such as in noise, or in reverberation conditions.

Skinner (1980) and Skinner, Karstaedt, & Miller (1982) used the Pascoe high frequency word test for the selection of hearing aids in individuals with a sensorineural hearing loss. It was found that Pascoe's high frequency word test was better in selecting the appropriate hearing aid compared to regular speech identification test.

Krishnan (2003) developed hearing aid test protocol for individuals with sloping high frequency loss. He took 30 individuals with 11 gradually sloping, 13 steeply sloping and 6 precipitously sloping hearing loss individuals for testing. An analogue behind-the-ear (BTE) hearing aid was selected using the POGO II formula (Schwartz, Lyregaard & Lundh, 1988). High Frequency Kannada Speech Identification Test (HF-KSIT) developed by Mascarenhas (2002) was used in testing the subjects both in unaided and aided condition, at two signal-to-noise ratio (+5 and +10 dB). The results indicated that there was significant difference between the unaided and the aided condition for both the word and sentence subtests across the audiometric slopes. Also in unaided and aided condition, a significant difference was observed between the +5dB and +10dB SNR for the word subtest. Thus, the word or the sentence subtest in the presence of noise could be effective in selection of hearing aids for sloping high frequency hearing loss.

From the above discussed studies, it is clear that individuals with a high frequency hearing loss requires speech test that are sensitive to their problems. The use of high frequency word tests was found to be better in selection of appropriate hearing aids. It was also suggested that speech test may be done in the presence of noise which could prove effective in hearing aid selection for sloping high frequency hearing loss.

2.6 Review of High Frequency Speech Identification Tests

High-frequency word lists have been developed in the past both in English and several other Indian languages. These lists concentrate on words that contain a preponderance of high-frequency consonants, which are frequently missed by patients with sensorineural hearing losses. They are originally designed to enhance the ability of speech recognition tests to distinguish performance differences between hearing aids, but can also be used for other clinical purposes.

Reviewing earlier studies on high-frequency speech identification tests revealed many tests. These tests differ either in terms of the length of the speech material (syllables or words or sentences) or in the language of the test material. Attempts were made to develop speech materials in respective languages in the past. And India, a country of language diversity requires separate test list in each language as almost each state has its own native language and large number of individuals in the state know only their native language.

The various Speech Identification Tests developed in different languages are given as follows:

2.6.1 High-Frequency Speech Identification Test in English:

- Gardner High Frequency Word Lists (Gardner, 1971)
- The Pascoe High-frequency Test (Pascoe, 1975)
- The California Consonant Test (Owens & Schubert, 1977)

2.6.2 High-Frequency Speech Tests in Indian Languages:

- The Speech Identification Test for Hindi and Urdu Speakers (Ramachandra, 2001)

- High Frequency – Kannada Speech Identification Test (Mascarenhas, 2002)
- High Frequency – English Speech Identification Test (HF-ESIT) (Sudipta, 2006)
- High Frequency Speech Identification Test in Tamil (Sinthiya, 2009)
- High frequency Speech Identification Test in Telegu (Ratnakar, 2010)

4.6.1 High frequency speech identification test in English:

High-frequency word list were first developed in English languages which were initially designed to enhance the ability of speech recognition tests to distinguish performance differences between hearing aids, but can also be used to test speech perception abilities in individuals with high frequency sensorineural hearing loss.

Gardner (1971) compiled list of words that contained consonants of high frequency spectral energy and used it for testing speech discrimination in cases of high frequency hearing loss. Though it was initially designed for application of hearing aid selection it was reported to be useful in other clinical purposes . The design consisted of high frequency word with seven voiceless consonants /p, t, k, s, f, θ, h/ in conjunction with the a single vowel, /i/.These consonants have been known to be confusing in individuals with high frequency hearing loss. There are fifty words arranged in random order and assigned alternatively to two lists with twenty five monosyllabic words in each.

Pascoe (1975) developed another High frequency word list to assess the speech perception abilities of hearing impaired individuals. The list includes fifty monosyllable words containing phonemes that are difficult for hearing impaired. Three vocalic nuclei were used /I/, /ai/ and /ou/ in order to increase the weight of the consonants in the correct identification of the vowels**.**It was found to be useful for hearing aid evaluation as well as checking perception ability in the presence of noise.

Owens and Schubert (1977) developed California Consonant Test (CCT) to be used with hearing impaired subjects. It is a multiple choice test for consonant identification consisting of 100 items. They believed that the clinical test should be developed such that it permits phoneme variation in only one position. A computer-assisted analysis was done for the test responses in 550 individuals with hearing loss. The results showed that the test was sensitive to high frequency loss as compared to individuals with relatively flat hearing configuration. According to the authors, the reliability of the California Consonant Tests is high and it can be used for rehabilitation procedures and in hearing aid comparisons.

2.6.2 High frequency speech test in Indian languages

Singh and Black (1996) reported that an individual's perception of speech can be greatly influenced by their mother tongue. De (1973) found that people consistently had better and optimum identification scores in their mother tongue as compared to other languages. Administering the test in a subject's native language is considered ideal. Since India is a country of language diversity, separate word lists are needed and intended for each native language.

Ramachandra (2001) developed high-frequency speech identification test in India for Hindi and Urdu speakers. The objective was to develop a list of meaningful, familiar, high frequency monosyllabic CVC words which can be used common to both Hindi and Urdu language. The test material consist of a list of 50 high frequency words which were rated as most familiar by a group of native speakers. The first list consisted of high frequency phonemes in the initial position and second list consisted of high frequency phonemes in the final position in a word.The developed test was found to be more sensitive compared to common speech discrimination test for Indians developed by Mayadevi (1974). And, no significant differences between the groups of Hindi and Urdu speakers were seen for the sensation levels from 0-40dB at 0.05dB level of significance.

Mascarenhas (2002) developed a speech identification test in Kannada for testing adults with high frequency hearing loss. The test consists of three lists of high frequency phonemes with equal distribution of high frequency sounds including bisyllabic and trisyllabic words. The test was administered randomly on 30 individuals with normal hearing sensitivity and 30 individuals with high frequency loss. The utility of the test was also checked by administering the test on five individuals with a high frequency loss, with and without hearing aids. The results were compared with those obtained with the "Common Speech Discrimination Test for Indians" (Mayadevi, 1974).The high frequency hearing loss group obtained poorer scores on the developed word subtest compared to the sentence subtest, which indicate that the former was more sensitive to detect the perceptual problem. The sentence subtest was unable to differentiate subjects with a HFHL from normal subjects. To make the sentence subtest more sensitive it can be administered in the presence of background speech noise.

Sudipta (2006) developed speech identification test for Indian English speakers to assess the perceptual problems of individuals with HFHL. Test was developed as English spoken in India is different from that spoken by native English speakers in European countries and United States in terms of vocabulary and pronunciation. The test includes four word lists and four sentence subtest. The test was administered on 30 normal hearing subjects and 10 sloping hearing loss subjects. The scores were compared with English monosyllabic word test (Rout, 1996). Results indicated that word subtests were more sensitive compared to sentence test in identifying the perceptual deficits. Also, a significant improvement was observed in aided and unaided condition in individuals with HFHL. The test was considered to be useful in selection of hearing aids.

Sinthiya (2009) developed speech identification materials in Tamil for testing individuals with high frequency sloping hearing loss. The test consisted of three lists, two bisyllabic word lists and one trisyllabic word lists which was administered on 100 normal hearing individuals. Since the test was administered only on normal hearing individuals, utility needs to be checked on individuals with high frequency hearing loss. The test was considered to be useful to identify speech perceptual deficits in individual with sloping high frequency hearing loss in both diagnosis and selection of hearing aids.

Ratnakar (2010) developed speech identification materials in Telugu for testing individual with high frequency sloping hearing loss. The test consisted of 50 bisyllabic words divide into two half lists, and one trisyllabic word list, containing 25 words each. The test was administered on 100 normal hearing individuals who were native speakers of Telugu and identification scores were obtained. To check the utility of developed list, it was also administered on 5 individuals with high frequency sensorineural hearing loss and results indicated significant poorer performance compared to normal hearing group. Hence, the test was considered sensitive to sloping high frequency hearing loss and it can be utilized in both diagnosis and selection of hearing aids.

2.7 FACTORS AFFECTING SPEECH AUDIOMETRY

In selecting and administering the most appropriate type of test material, audiologists must consider the demands placed on the individual being assessed within the chosen test conditions. There are several factors which should be considered that include the linguistic demands of test items, their delivery style and form, determining the intensity or intensities at which testing will be done, and the language abilities of the individual being evaluated.

2.7.1 *Word familiarity*

"Speech audiometry involves material that is inherently linguistic in nature" (Gelfand, 2001). Words for any speech test should be chosen carefully considering the frequency and familiarity of each item. Word familiarity (i.e. whether the stimuli is known or understood by the listener) significantly affects performance during speech recognition testing (Owens, 1961). Issues regarding word familiarity have been addressed since the development of the very first traditional word lists. One needs to avoid any unfamiliar words being included in materials for the population they are intended for. Word frequency is also another related factor which has a well-established effect on performance, namely "those that occur more frequently are more easily recognized" (Gelfand, 2001).

2.7.2 *Full Lists versus Half Lists*

As per the format of traditional word recognition materials, word lists are typically 50-words in length. However, in an effort to save time, it has become the clinical practice of most audiologists to administer half-lists of 25-words, weighting each correct response or word as 4%. Objections against this procedure include (a) one half list may not equally contain the same number of audible phonemes, (b) the difficulty of recognizing or discriminating words may be significantly different between the two halves of a list, and (c) splitting a list compromises the phonetic of phonemic balance, although it is given that this standard is not truly attainable (Gelfand, 2001). In contrast, Tobias (1964) asserts that phonetic/phonemic balance is unnecessary in "useful diagnostic" testing, as half-list do in fact measure the same features as full lists. Thornton and Ruffin (1978) also provide evidence that half-lists produced reliable results as do full 50-word lists. Similar results were obtained by Vandana (1998) showing no significant difference in the percentage of identification between full list and half lists.

2.7.3 *Phonetically balanced word lists.*

There appears to be considerable doubt as to the reality of phonetically balanced materials. Regardless, materials continue to be created according to this principle. Martin, Champlin, and Perez (2000), compared the WRS of PB and non-balanced word lists on subjects with normal hearing and sensorineural hearing loss. Their results indicated that the scores were near identical, bringing into question whether word lists are or need to be phonetically balanced.

2.7.4 *Open versus closed response sets.*

Open response sets are commonly used to assess speech recognition which requires the listener to repeat the presented stimuli (the word, phrase, or sentence) without "prior knowledge" (Gelfand, 2001) of the possible answer. Both the CID W-22 and NU-6 use this method of response. In fact, response possibilities are almost infinite, as the listener is encouraged to say whatever they heard, guessing if necessary. Closed response sets require the listener to indicate their answer from a discrete number of answer choices; for example, pointing to a picture, an actual object, or choosing the correct word from a designated list. Such response conditions are naturally most suited to children and other individuals needing special considerations. Examples of the most well-known closed set word recognition tests include the Rhyme Test (Fairbanks, 1958), California Consonant Test (Owens & Schubert, 1977), Picture Identification Task (PIT; Wilson & Antablin, 1980), Word Intelligibility by Picture Identification (WIPI; Ross; Lerman, 1970), and the Northwestern University Children's Perception of Speech (NUCHIPS) test (Elliot & Katz, 1980).

2.7.5 *Carrier phrases*

As far as carrier phrase is concern, researches on the significance of using carrier phrases such as, “say theword _____,” or “you will say _____,” have generated mixed results and opinions. Some studies indicated that they make a significant difference in performance (Gladstone & Siegenthaler, 1971; Gelfand, 1975) and others to the contrary (Martin, Hawkins, & Bailey, 1962; McLennan &Knox, 1975). It is thus possible and understandable that some listeners perform better with such cues, but equally possible is their potential to become irritated or distracted by such repetition (Gelfand, 2001). In certain cases, carrier phrases are desirable because it assists in monitoring the VU meter and hence in speaking at proper intensity.

2.7.6 *Presentation Level*

Testing at more than one intensity level is strongly encouraged as it assists the administrator in finding the listeners highest WRS. Routine testing is usually done at 30 to 35 dB SL (relative to SRT) for those with normal hearing, and 40 dB SL for the hearing impaired (Gelfand, 2001). It is thought that many audiologists perform this kind of testing at most comfortable level (MCL), but this is not advisable because the MCL is actually a range rather than a level (Gelfand, 2001). The highest speech recognition scores are often above the individual’s MCL (Clemis & Carver, 1967; Ullrich & Grimm, 1976; Posner & Ventry, 1977; Dirks & Morgan, 1983). It was reported that PB-Max for male voice presentations of CID-W-22 and NU-6 test words occurs at around 30 dBSL (ref to SRT) for normal hearing individuals. For other tests like the PB-50 and Maryland CNC tests, PB-Max for similar subjects is reported to occur at approximately 45 dBSL (ref to SRT).

2.7.7 *Recorded voice versus live voice*

The physical attributes of speech vary considerably from person to person. Word recognition materials are made available in written form or as recorded tests. Written materials require the clinician or audiologist to say the words through a microphone. Thus, the intelligibility of the same word is affected by differences among talkers, as even repeated productions from the same talker over time are not the same. Kreul, Bell, and Nixon (1969) even claim that the same word list spoken by two different talkers constitute two different tests. This claim is supported by evidence from several studies where significantly different speech recognition results were obtained from common listeners tested with different talkers (Penrod, 1979; Gengel & Kupperman,1980; Hood & Poole, 1980; Bess, 1983) and the same talker over time (Brandy, 1966).

These concerns constitute strong evidence for using recorded test materials whenever possible. Martin and Clark (2009) further assert that recorded materials claim advantage over live voice as they "provide a consistency of presentation…independent of the…clinician". With the advent of the CD and other digital technology, clinicians can retain the flexibility and time once ascribed to live voice testing. Of course in special situation live voice may be more appropriate for the special needs of patients or when no recorded version of the test is available.

2.7.8 *Foreign language influences and implications*

As mentioned before, word recognition materials are inherently linguistic and thus their use may implicate factors such as phonology and morphology and "exacerbate word familiarity effects" (Gelfand, 2001). Gat and Keith (1978) showed that foreign speakers typically obtain lower scores on English speech recognition tests than native English speakers. The ideal solution is that each person should be tested in his or her own native language by a native or at least a fluent speaking audiologist. The least desirable alternative is to test a patient with materials in an unfamiliar language, which confounds the results because of the linguistic mismatch between stimuli and the patient's language abilities. If faced with such a difficult situation, all efforts should be made to obtain material in the desired language and perform audiometric testing using closed-set responses. In this way, "recorded test items can be presented in the patient's language and his/her responses can be scored without being influenced by the perceptions of the clinician" (Gelfand, 2001). Closed-set responses can be identifying pictures or the listener may write down or circle their own response from a given answer bank.

2.8 The Mizo Language

Constructing and creating Mizo speech materials required a clear understanding of the Mizo language including its classification, use, and linguistic features. The following sections provide a general description of these topics.

2.8.1 *History and country of use.*

According to History, the Mizo language belongs to the Kukish branch of the Tibeto-Burman family of languages. The numerous clans of the Mizo had respective dialects, amongst which the Lushai (Lusei, by Mizo themselves) dialect was most common, and which subsequently became the Mizo language and the *lingua franca* of the Kuki peoples due to its extensive and exclusive use by the Christian missionaries

(Lalthangliana, 2001, 2012). As of now, the Mizo language is natively spoken by Mizo people in Mizoram, a state in the Indian Union; Chin State of Burma and in the Chittagong Hill Tracts of Bangladesh. The language is also known as Lushai (by the Colonial British), as Lusei people are the first clan who have an external exposure. For this reason, even in most of modern writings Lushai (or Lusei) is being used instead of Mizo.

2.8.2 *Orthography and phonology*

Christian missionaries who came to India during 1894s started developing an alphabet for the language by adapting the Italian alphabet and the Hunterian system of transliteration. The Mizo alphabet has 19 consonants and 6 vowels. The consonants are b, ch, d, f, g, ng, h, j, k, l, m, n, p, r, s, t, ṭ, v, z.The 6-vowels are a, aw, e, i, o and u.A circumflex ^ was later added to the vowels to indicate long vowels, viz., â, ê, î, ô, û, which were insufficient to fully express Mizo tone (Ralluaii, 2001).

2.8.3 *Phonetics*

In Mizo, large groups of words are obviously related to one another both in sound and in meaning, with proper regular systematic pattern. For example: *puar* ("slightly bulging"), *na*("to feel pain"), *lang*("to float"), *huan*("garden"), *thiam* ("to know", such as languages or knowledge), *thau* ("fat"), *lian* ("big"), *buai* ("to be troubled of"), *pem* ("to move from one town or city to another"), *puan* ("a piece of cloth").

2.8.4 *Tone*

Mizo is a tonal language, in which differences in pitch and pitch contour can change the meanings of words. Tone systems have developed independently in many of the daughter languages largely through simplifications in the set of possible syllable-final and syllable-initial consonants. Typically, a distinction between voiceless and voiced initial consonants is replaced by a distinction between high and low tone, while falling and rising tones developed from syllable-final *h* and glottal stop, which themselves often reflect earlier consonants.

2.8.5 *Grammar*

Mizo contains many analyzable polysyllables, which are polysyllabic units in which the individual syllables have meaning by themselves. In a true monosyllabic language, polysyllables are mostly confined to compound words, such as "lighthouse". The first syllables of compounds tend over time to be de-stressed, and may eventually be reduced to prefixed consonants. The word *nuntheihna* ("survival" is composed of *nung* ("to live"), *theih* ("possible") and *na* (a nominalizing suffix); likewise, *theihna* means "possibility". Virtually all polysyllabic morphemes in Mizo can be shown to originate in this way.

2.8.6 *Dialects*

The Mizo dialects can be classified broadly as ten groups - Aso, Chho, Halam, Hmar, Lai, Lusei, Gangte, Mara, Miu-Khumi, Paite and Thado-Kuki.Many of these dialects are being used in different parts of the Indian states particularly in North-Eatern region like Manipur (e.g. Hmar, Gangte), Meghalaya (e.g. Lusei, Hmar), Assam

(Gangte, Lusei,) and Mizoram District (Lusei, Hmar). It also has been found to be a dialect of Chin-state in Burma (e.g. Paite, Chho, Lai and Miu-Khumi). There are around 700,000 speakers of Mizo dialects (Lusei (Duhlian), Lusei (Hualngo)): 674,756 speakers in India (2001 census); 1,041 speakers in Bangladesh (1981 census); 12,500 speakers in Burma (1983 census).

2.9 Mizo Speech Audiometry Materials

At present, PB words and Spondee words developed by Lalhmangaihi (2009) is only available material for Speech Audiometry. However, High frequency speech materials are still unavailable in Mizo language. Thus, it is of a great importance that high frequency speech materials to be developed for native speakers of Mizo.

CHAPTER III

METHOD

The following method was adopted to verify the objectives of the study. The study was conducted in the following two phases.

Phase 1: The development of high frequency word list.

Phase 2: Standardization of the test material

3.1 Phase 1:The development of high frequency word list

The following steps were followed to arrive at the high frequency word list:

3.1.1 *Selection of words*

Both monosyllabic and bisyllabic words with good redundant cues were selected for the construction of test list. These words were collected from various sources like dictionaries, newspapers, articles, and books. Words having a phoneme /k/, /t̪/, /s/,/d̪/, /r/, /ʤ/, and /l/were preferred for inclusion as these phonemes have spectral energy mostly distributed above 1000 Hz frequency (Hughes & Halle, 1956). From vowels, vowels like /i/ and /e/ were preferred as these vowels show higher F2 and F3 formants (Copper, Liebermann, Delattre, Borst, &Gerstmann, 1952). Totally, 445 words were collected from the various sources mentioned.

3.1.2 *Assessment of familiarity to the selected words*

To assess the familiarity of the words selected, 10 adults (5male & 5female), who were native speakers of Mizo were chosen and instructed to rate the selected words according to their level of familiarity. A three point scale of familiarity was administered based on the frequency of occurrence: most familiar, familiar and unfamiliar.

Operational definitions of these terms were as follows:

1. Most familiar words are those used commonly
2. Familiar words are those words used occasionally but familiar and,
3. Unfamiliar words are those words that are not used by the participants.

A printed version of words was given to the individuals for the assessment with instruction carefully written to follow while rating each word. Each participant was asked to tick the score suitable. Only those words that were rated as most familiar were selected for the construction of test lists. Thus,378 words were selected out of 445 words.

3.1.3 *Long-term average speech spectrum (LTASS) on familiar words*

After the assessment of familiarity, LTASS was done to determine if the most familiar words constitutes spectral information predominantly in the higher frequencies. This was done to see if the selected word lists possess the required spectral information. It was a necessary procedure because the spectral information of the phonemes /k/, /t̪/, /s/, /d̪/, /r/, /ʤ/, and /l/ could differ depending on the context and hence the so called high frequency word may not be having high frequency spectral information. To do this, 378 words that were rated as most familiar were assessed for the spectral information using LTASS.These words were recorded in a sound treated room using Computerize software spoken by adult female who was a native speaker of Mizo. The recording was done at 16 kHz sampling rate and 16 bit quantization using Adobe

Audition (version 3.0) software and the samples were stored into a computer. LTASS was derived using PRAAT software by feeding the audio samples one by one into it and the spectral information was determined manually.The peak frequency of the spectra which have highest energy concentration was taken as the target parameter.

Peak frequency determined in LTASS showed that out of 378 words, there were 250 words having highest energy above 1000 Hz. These 250 words were further categorized based on different cut off peak frequency (1.0, 1.5, 2.0, 2.5, & 3.0 kHz). In the present study it was decided to use words with peak frequency 2 kHz and above to make it a more sensitive test. There were 186 such words with peak frequency of 2 kHz and above. Out of 186 words, 150 words were randomly selected for the construction of high frequency word list.

The spectrum derived from LTASS for a word is shown in the Figure 3.1.

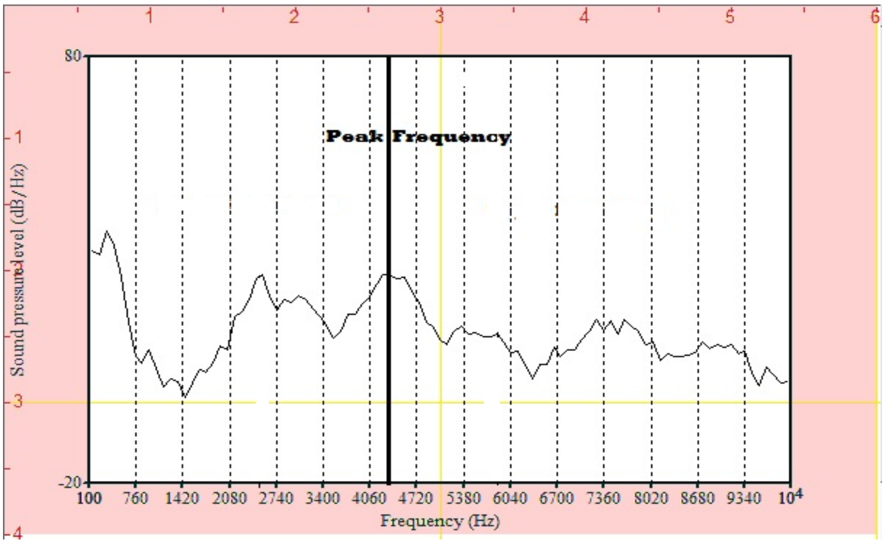

Fig 3.1: Spectrum derived from LTASS for a representative word (e.g. beisei)

3.1.4 *Construction of word subtests*

The 150 words that were selected based on LTASS results and having highest energy above 2 kHz were further categorized into monosyllabic and bisyllabic words. There were 100 monosyllabic words and 50 bisyllabic words. The 100 monosyllabic words were divided into two lists each of which were further divided into two half lists, each list containing 25 words. There was 50 Bisyllabic words which were also divided into two half lists, each list containing 25 words. The frequency of occurrence of high frequency sounds was maintained same in each of the lists containing both monosyllabic and bisyllabic words. The monosyllabic (four half lists) and bisyllabic (two half lists) is given in the appendix (I, II, & III).

3.1.5 *Recording of the test material.*

Recording of the test material (150 selected words) was done in a sound treated room as per ANSI guidelines (1999). Three adult females, who were native speakers of Mizo was selected for recording the tests words. The recording was done using Adobe Audition (version 3.0) software and the recorded materials were perceptually rated. The speaker who spoke with the best clarity and fluency was chosen for the audio recording of the final test list. The microphone was placed at a distance of 5 inches away from the mouth of the speaker. The VU meter was monitored within optimum levels during the recording. The speaker was instructed to say the words with her normal pitch and to keep the loudness constant across the words. The recording was done using 44.1 Hz sampling rate and 16 bit quantization in mono channel. The intensity of each word was edited as a single utterance using Adobe Audition software to obtain the same average RMS power as a 1000Hz calibration tone in an attempt to equate test word audibility

(Harris et al., 2004; Wilson & Strouse, 1999). After editing, each word was saved individually as wav. file.The recorded material was also edited to carry out noise and hiss reduction. The inter stimulus interval between the two words was set to 5 seconds. The material was then copied onto an audio compact disc using a compact disc writer.

3.2 Phase II: Standardization of the test material

The developed test material was standardized by fulfilling the following criteria and procedures:

3.2.1 *Subjects*

The developed test MHF-SIT was normalized and standardized by obtaining speech identification scores on 100 native speakers of Mizo language (50male & 50female). The participants were in the age range of 18 to 30 years. By self report, all participants were native speakers of Mizo and considered Mizo to be their first language.

3.2.2 *Subject selection criteria*

All the participants considered for the tests went through initial interview where information was collected through case history and results of pure tone audiometry and immittance audiometry was used to interpret the current status. The following considerations were taken for the inclusion of subject:

- No history of hearing loss, ear disease, trauma, ototoxic drug intake or ear operation.

- Bilateral normal hearing sensitivity in the frequency from 250 Hz to 8000 Hz for air conduction and 250 Hz to 4000 Hz for bone conduction as obtained by modified version of Hughson & Westlake procedure (Carhart & Jerger, 1959).
- Speech recognition threshold was ±12 dB (re: PTA 0.5, 1 & 2 kHz) in both ears. It was obtained by using Mizo spondee list developed by Lalhmangaihi (2009) at 20 dBSL (re: PTA).
- Speech identification score of >90% at 40 dB SL (re: SRT) in both ears. It was carried out by using monosyllabic and bisyllabic words in Mizo (Lalhmangaihi, 2009).
- Bilateral A-type tympanogram and acoustic reflex present (Ipsilateral & contralateral reflex) in both ears to ensure normal middle ear functioning. Tympanometry using 226 Hz probe tone and Acoustic Reflex Test on 5 octave frequencies (i.e., 250, 500, 1000, 2000, and 4000 Hz) was administered.
- No current illness that might affect the hearing and overall performance.
- No neurological problems.

3.2.3 *Testing environment*

All the evaluations was carried out in an acoustically treated two-room situation as per ANSI S3.1 (1991).

3.2.4 *Instrumentation*

- A calibrated single channel audiometer (Classic II) coupled with acoustically matched TDH-39 supra aural headphone and Radio ear B-71 bone vibrator was utilized to estimate pure tone threshold, speech recognition threshold and speech identification score.
- A calibrated immittance meter (Amplaid-760) was used for obtaining tympanometry and acoustic reflex.
- A Desktop Computer of Core 2 Duo processor with adobe audition (version 3.0) software was used to record and present the developed test material.

3.2.5 *Procedure*

After the estimation of pure tone threshold, speech reception threshold (SRT) and speech identification scores (SIS), the high frequency word identification list developed in Phase 1 was played (through computer plugged to audiometer) at 40 dBSL (wrf: SRT), delivering the stimulus through headphones. An external output of the audiometer was calibrated prior to testing each subject to 0 VU, using a 1000 Hz calibration tone. All participants were tested monaurally using the developed lists. The order of the lists was randomized to avoid order effect and an open set response in the form of oral response was obtained.All subject responses was scored by a native Mizo interpreter throughout data collection. Responses were only marked correct if they matched the target stimuli in both pronunciation and lexical tone. Prior to the administration of word recognition testing, each subject was given the following instructions in English or in Mizo:

"You will hear lists of Mizo words a number of times at specific level. One word will be followed by another word.The silent gap between each word will be about 5 seconds. Please listen carefully and repeat out loud the word that you hear. If you are unsure of a word, you are encouraged to guess. If you have no guess say, *I don't know*, or wait silently for the next word. Do you have any questions?"

3.2.6 *Scoring*

After the estimation of MHF-SIT the responses was scored as follows:

- Each correct response was given a score of 1
- Each incorrect response was given a score of 0

The raw score was converted to percentage as below:

$$\textbf{Total score (\%)} = \frac{\text{Total number of correct responses}}{\text{Total number of words presented}} \times 100$$

3.3 Statistical Analysis

Statistical Package for the Social Sciences (version 16) software was used to carry out the statistical analysis. Descriptive statistics to find out the Mean and Standard Deviation, Independent *t*-test to compare the Mean scores of variables, one way ANOVA, repeated measure ANOVA and Bonferroni post hoc test were the statistical test used.

CHAPTER IV

RESULTS AND DISCUSSION

Results of the present study are described and reported under the following headings:

4.1 Development of the high frequency word lists.

4.2 Development of the normative for the Mizo High Frequency Speech Identification test in Mizo language.

4.3 Comparison of speech identification scores across lists to check the equality of different lists.

4.1 Development of the high frequency word list/s

4.1.1 *Selection of the words and their familiarity*

Initially a total of 445 words were collected which included both monosyllabic and bisyllabic words. These words were then rated for their familiarity using 10 native (5 female & 5 male) speakers of Mizo. As a result, out of 445 words 378 were rated as most familiar. Only these 378 words were considered for the development of Mizo high frequency speech identification test (MHF-SIT).

4.1.2 *Results of LTASS of Target words*

LTASS was done for selected 378 words to validate the spectral information. This was necessary to decide whether the words could be included in the final list. LTASS revealed the frequency range and predominant energy concentration for each word. The peak frequency of the spectra from the LTASS was considered.

LTASS results showed that out of 378 words, 250 words had highest energy concentration at and above 1 kHz. These 250 words were considered for the development of the final list. The 250 words considered were further categorized based on the different cut off peak frequency (1.0, 1.5, 2.0, 2.5, & 3.0 kHz) as given in the Table 4.1.

Table 4.1*: Cut off frequency of selected 250 words.*

Cut off Frequency (kHz)	**Number of words**
1.0	250
1.5	213
2.0	186
2.5	124
3.0	68

From the data given in Table 4.1, it is clear that 250 words had predominant spectral information above 1 kHz. It is also evident that as the cut off frequency increased, the number of words decreased.

Although all 250 words showed spectral information higher than 1 kHz, in the present study only those words that have cut off frequency at and above 2 kHz were included for the final construction of the list. Sinthiya (2009) statistically compared spectral peak frequency between regular standardized phonetically balanced speech identification test and High frequency Speech Identification Test in Tamil. Results indicated that words with predominant spectral information above 2 kHz were more sensitive in detecting speech perception deficits in individuals with high frequency hearing loss, compared to words with energy above 1 kHz. Hence, decision to use words with cut off frequency above 2 kHz as inclusion criteria for the construction of final word lists is justified. Thus, there were 186 words available with peak frequency above 2 kHz, from which 150 words were randomly selected for the final list. These 150 words consisted of 100 monosyllabic and 50 bisyllabic high frequency words.

4.1.3 *Construction of the word subtests*

Word subtest was constructed from selected 150 words consisted of 100 monosyllabic and 50 bisyllabic words. Thus, based on this, three separate lists were prepared; List 1 and List 2 had 50 monosyllabic words each while the List 3 had 50 bisyllabic words. This was done because the redundancy in bisyllabic words could be more than that of monosyllabic words which could affect speech identification scores (Hirsh, Silverman, Reynolds, Eldert& Benson, 1952). It was also presumed that depending on the level of word difficulty in these lists speech identification scores could differ and a normative developed combining these words within the same list may be erroneous. Hence, separate monosyllabic and bisyllabic list were prepared.

Further, 50 monosyllabic words in both List 1 and List 2 were divided into two half list with 25 words each, thus, there were 4 half list of 25 words each. Similarly, List 3was also divided into two half list with 25 words each. This was done to provide a shorter version of the test which could be useful when the complete list cannot be administered due to time constraints. While dividing the lists, attempt was made to keep the frequency of high frequency sounds similar in all the half lists.

Descriptive statistics was done to find out the Mean and Standard Deviation (SD) of the spectral peak of 150 words selected for the final list. Table 4.2 shows the Mean and Standard Deviation of spectral peak frequency obtained from LTASS of all the 6 lists.

Later, one way ANOVA was done to compare the equality in peak frequency energy concentration across 6 lists. The results indicated that there was no significant difference between the spectral peak frequencies of the words in the lists [$F (5, 144) = 0.013$, $p>0.05$]indicating that all 6 lists had similar high frequency energy concentration.

Table 4.2: *Mean and Standard Deviation (SD) of spectral peak frequency on selected word list.*

List	Number of words	Mean Peak frequency (Hz)	SD
List 1: Half list 1	25	2937.68	421.96
List 1: Half list 2	25	2920.44	374.92
List 2: Half list 1	25	2926.36	450.45
List 2:Half list 2	25	2928.72	568.13
List 3: Half list 1	25	2946.60	587.99
List 3: Half list 2	25	2948.64	546.70
Total	150	2934.74	489.83

4.2 Development of the normative for the Mizo High Frequency Speech Identification Test (MHF-SIT)

Normative was established for the developed test on 100 normal hearing individuals (50 Females & 50 Males) who were native speakers of Mizo. Speech identification scores were obtained for all 6 half lists for each ear separately. Words were presented randomly to both ears. The Mean and standard deviation of speech identification scores obtained for six lists are given in the Table 4.3.

4.2.1 *Comparison between the ears*

Speech identification scores obtained for the left and right ear was compared for all the six lists (Table 4.3). It was observed that majority of the normal hearing individuals obtained almost 100% speech identification scores in left as well as right ear. Later, one way ANOVA (Table 4.4) was performed for the purpose of checking the effect of list, ear and interaction between the two. Results of one way ANOVA showed no significant difference between the speech identification scores obtained in two ears. Hence, the data from left and right ear were combined for further statistical analysis.

Table 4.3: *Mean and Standard Deviation (SD) of MHF-SIT scores in normal hearing individuals.*

Lists	Ears	Mean (%)	Range	1 SD
List-1 Half list 1	**Right**	99.5	100 - 96	1.25
	Left	99.5	100 - 96	1.30
	Total	99.5	100 -96	1.27
List-1 Half list 2	**Right**	99.6	100 - 96	1.10
	Left	99.6	100 - 96	1.20
	Total	99.6	100 - 96	1.17
List-2 Half list 1	**Right**	99.7	100 - 96	1.09
	Left	99.6	100 - 96	1.15
	Total	99.6	100 - 96	1.11
List-2 Half list 2	**Right**	99.5	100 - 96	1.13
	Left	99.6	100 - 96	1.20
	Total	99.5	100 - 96	1.25
List-3 Half list 1	**Right**	99.8	100 - 96	0.685
	Left	99.9	100 - 96	0.562
	Total	99.9	100 - 98	0.626
List-3 Half list 2	**Right**	99.8	100 - 96	0.876
	Left	99.8	100 - 92	0.971
	Total	99.8	100 - 92	0.922

Table 4.4: *One-way ANOVA results across lists.*

List	F	p
Word-List-1 Half list 1	0.049	0.826
Word-List-1 Half list 2	0.058	0.881
Word-List-2 Half list 1	0.064	0.801
Word-List-2 Half list 2	0.202	0.653
Word-List-3 Half list 1	0.203	0.653
Word–list-3 Half list 2	0.093	0.760

The present result showed that normal hearing individuals obtain almost 100% speech identification score on high frequency words. This finding is in agreement with several earlier studies (Schwartz &Surr, 1979; Mascarenhas, 2002; Sudipta, 2006; Sinthiya, 2009; Ratnakar, 2010). The lowest score obtained among the 100 subjects was 92%. Thus, it can be inferred that the specificity of the Mizo High Frequency Speech Identification Test (MHF-SIT) is good. Earlier studies (Schwartz &Surr, 1979; Mascarenhas, 2002; Sudipta, 2006; Ratnakar, 2010) have checked for the sensitivity with high frequency sensorineural hearing loss. However, due to time constraints that was not among the objectives of the present study.

4.2.2 *Comparison between Males and Females*

The speech identification scores were also compared across the 6 lists for males and females (50 males & 50 females). One way ANOVA was performed to see whether there was a significant difference in the speech identification scores between male and female subjects. To do this, speech identification scores of both ears (right and left ears) obtained from males were compared with that of females separately for each of the 6 lists.

Table 4.5: *One way ANOVA for Speech Identification Scores between male and female subjects.*

	Gender	Ear	Mean	SD	p
List-1: Halflist-1	**Female**	*Right*	99.6	1.21	0.75
		Left	99.3	1.48	0.22
	Male	*Right*	99.5	1.31	0.75
		Left	99.6	1.09	0.22
List-1: Halflist-2	**Female**	*Right*	99.6	1.09	0.73
		Left	99.7	0.95	0.18
	Male	*Right*	99.6	1.21	0.73
		Left	99.4	1.40	0.18
List-2: Halflist-1	**Female**	*Right*	99.5	1.31	0.14
		Left	99.5	1.31	0.29
	Male	*Right*	99.8	0.79	0.14
		Left	99.7	0.95	0.29
List-2: Halflist-2	**Female**	*Right*	99.4	1.40	0.54
		Left	99.4	1.40	0.18
	Male	*Right*	99.6	1.21	0.54
		Left	99.7	0.95	0.18
List-3: Halflist-1	Female	*Right*	99.8	0.79	0.56
		Left	99.8	0.79	0.15
	Male	*Right*	99.9	0.56	0.56
		Left	100	0.00	0.15
List-3: Halflist-2	**Female**	*Right*	99.7	0.95	0.65
		Left	99.8	0.79	1.00
	Male	*Right*	99.8	0.79	0.65
		Left	99.8	1.13	1.00

The results revealed that there was no significant difference between the speech identification scores obtained between males and females in all the 6 lists as depicted in Table 4.5. This finding was in agreement with earlier studies (Kruger, 2010) where comparison was done to determine to see presence of any significant statistical differences between males and females on word recognition scores in native speakers of Samoan and results showed no significant difference.

4.3 Comparison of Speech Identification Scores across lists to check the equality of different lists

To verify whether there is any significant difference in the speech identification scores across the 6 lists, repeated measures ANOVA was done. The results of repeated measure ANOVA indicated that there was a significant main effect of word list on speech identification scores[$F (5, 995) = 4.106$, $p < 0.01$]. To obtain pair wise comparison across the 6 lists, Bonferroni post hoc analysis was carried out. The results of Bonferroni test are shown in the Table 4.6

Results showed no significant difference ($p>0.05$) in speech identification scores between 4 monosyllabic half lists, and between 2 bisyllabic half lists. Also, there was no significant difference ($p > 0.05$) between monosyllabic word (wordlist-2) half list 1 and the bisyllabic word lists in terms of speech identification scores. However, significant difference was seen between bisyllabic word lists (Halflist-1 of List-3) [$p < 0.05$] and other word lists, with bisyllabic word lists showing better speech identification scores as compared to monosyllabic word lists. This improvement in speech identification scores for bisyllabic word list could be because of the redundancy of the bisyllabic words, which is easier to identify as compared to monosyllabic words. Similar result was also found in earlier studies done by Hirsh, Davis, Silverman, Reynolds, Eldert, & Benson (1952).

Table 4.6: *Results of Bonferroni post hoc test showing the pair wise comparison across the word subtests*

Lists	**List-1 Half list 1**	**List-1 Half list 2**	**List-2 Half list 1**	**List-2 Half list 2**	**List-3 Half list 1**	**List-3 Half list 2**
List-1 Half list 1		NS	NS	NS	***S***	NS
List-1 Half list 2	NS		NS	NS	***S***	NS
List-2 Half list 1	NS	NS		NS	NS	NS
List-2 Half list 2	NS	NS	NS		***S***	NS
List-3 Half list 1	***S***	***S***	NS	***S***		NS
List-3 Half list 2	NS	NS	NS	NS	NS	

Thus, although the results revealed that there was statistical difference, inspection of the mean speech identification scores obtained for the monosyllabic word lists and the bisyllabic word lists was above 99%. This indicates that the magnitude of the mean difference is very small and will not have any clinical importance. Hence, it can be concluded that any of the 6 word subtests can be used to assess the high frequency speech identification.

CHAPTER V

SUMMARY AND CONCLUSION

An individual needs good hearing ability in order to decode a message from a stream of sounds coming from a speaker for effective communication (Borden & Harris, 1980) and it is a known fact that a person with hearing loss will have communication problem. It has been well documented that individual with High frequency hearing loss will have effect speech perception (e.g., Corso, 1959). Perhaps, the major effect of high-frequency hearing loss on speech perception is degraded ability to perceive sounds whose spectral energy is dominated by high frequencies (including plosive, fricative, and affricate consonantal sounds). Studies have demonstrated that the pattern of perceptual deficits in high frequency hearing loss is similar to that observed in normal-hearing listeners deprived of high-frequency cues through the use of low-pass filtering (Wang, Reed, and Bilger, 1978).

The regular speech identification tests are standardized mostly on individuals having flat audiometric configuration. However, performance on speech identification obtained by using these test may overestimate speech perception and understanding in individuals with sloping or high frequency hearing loss as the spectral information below 2 k Hz where the hearing is normal could aid in perception. Studies have indicated the need to utilize the tests that are able to detect the perceptual problems of individuals with high frequency hearing loss. High frequency speech identification test will meet the needs of such individual with a sloping high frequency hearing loss in both diagnosis and selection of appropriate hearing aids.

The aim of the present study was to develop and standardize the Mizo high frequency speech identification test (MHF-SIT) in normal hearing individuals who are native speakers of Mizo language.

The development of the test material was conducted in two phases. In the first phase, 445 high frequency speech sounds were collected which were further rated for familiarity on 3 point rating scale and most familiar words were selected (378 words). The peak frequency of the most familiar words was obtained from LTASS, and based on the cut off peak frequency words were categorized, which showed that number words decreased as the cut off frequency increased. Based on the earlier research findings (Sinthiya, 2009), only those words having predominant spectral energy above 2 kHz were used for the construction of the word list (i.e. 150 words). Three lists were constructed, where List 1 and List 2 consisted of 2 half list, each having 25 monosyllabic words. Similarly, List 3 was also divided into 2 half lists of 25 bisyllabic words each. In the second phase, the test materials were administered on 100 normal hearing individuals who were native speakers of Mizo (18 – 30 years) and speech identification scores were obtained. The right and left ears were tested separately with all the 6 lists at 40 dB SL (ref. SRT).

The results showed that the normal hearing subjects obtained mean score of more than 99% for all the 6 lists. No significant difference across ear and gender was observed in speech identification scores across the lists. Further, pair wise comparison across the 6 half lists showed that any of the lists are equally comparable and can be used to obtain high frequency speech identification scores. However, the utility of test needs to be checked on individuals with high frequency hearing loss.

5.1 Utility of the Test

The Mizo High frequency Speech Identification Test (MHF-SIT) will be useful to identify and evaluate speech perceptual deficits in individuals with high frequency hearing loss. Speech perception abilities obtain using this test will give better estimate of the communication handicap that these individuals possess as compared to regular speech test. This could also be useful in the selection of appropriate amplification devices for individuals with high frequency hearing loss and auditory training of high frequency words.

5.2 Recommendations for Future Research

The current Mizo High frequency Speech Identification Test developed is suitable for native speakers of Mizo. The lexical items are judged to be appropriate for teens and adult-aged individuals only, and not for children. Thus, Speech Identification materials appropriate for Mizo speaking children needs to be developed and pose a valid topic for further research.

Another suggestion for further research includes testing Mizo subjects with words presented in background noise. All subjects who participated in the current study were normal hearing individuals and were tested in a quiet environment in a sound treated room. However, individuals with normal and impaired hearing rarely listen in such conditions as most daily communication occurs in the presence of noise. Indeed, Wilson and McArdle (2006) affirm that the most common complaint of hearing loss individuals is the loss of ability to understand speech in noisy environments, especially noise generated by several speech sources. It therefore becomes important to test word recognition in quiet and in noise despite increasing the length of an audiological evaluation in doing so (Wilson &McArdle, 2006).

Finally,further research is also needed to assess the effectiveness of the current materials in evaluating individuals with varying types and degrees of hearing loss, especially sloping high frequency hearing loss to standardize and determine the continuity of results among these different populations (McArdle& Wilson, 2006).

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APPENDIX: I

List-1

(Monosyllabic)

Half List - 1		Half List - 2	
sèr	se:ɾ	**sĭl**	sIl
dik	dIk	**zâwl**	ʒo:l
liak	ʔljak	**leih**	leIʔ
viàl	wIəl	**duk**	duk
bek	bɛ:k	**zâr**	ʒa:r
khing	k^{h}Iŋ	**khuár**	k^{h}uvar
zíng	ʒiiŋ	**zâl**	ʒa:l
kawlh	kɔlʔ	**râl**	rɑ:l
rit	rIt	**tír**	ti:r
tír	tiir	**rùi**	ruI
tlar	tlʔa:r	**suìh**	suiʔ
khăr	k^{h}a:r	**kut**	kut
ei	ʔe:I	**lâwr**	lɔ:r
phír	p^{h}iir	**sawl**	sɔ:l
thlâwk	t^{h}lɔ:k	**tleuh**	tleʊʔ
hlut	hlut	**kèl**	ke:l
tĭn	tIn	**chil**	t͡ʃIl
zêp	ʒep	**sîr**	si:r
ruh	ɾuʔ	**tlak**	tlʌk
thŭr	t^{h}u:r	**suăl**	suvʌl
hér	^{h}e:ɾ	**zuâr**	ʒuʌr
sûm	su:m	**rîng**	rIŋ
lêi	leI	**chhing**	ʧ^{h}i:ŋ
kêng	keŋ	**fĕi**	feI
zawh	ʒɔʔ	**thlâm**	t^{h}la:m

APPENDIX: II

List-2

(Monosyllabic)

Half List - 1		Half List - 2	
sûr	su:r	**siál**	sIɑl
dek	dek	**diăk**	dIɑk
lérh	lerʔ	**lâwr**	lo:r
zĭn	ʒIn	**zâwl**	ʒɔ:l
pùi	puI	**pel**	pel
vawt	vɔt	**khái**	k^ha:I
sêm	se:m	**zuih**	ʒuI^h
zŭng	ʒuŋ	**ruài**	ruvʌI
rî	ri:	**rîng**	rIŋ
pèr	pær	**zĕi**	zeI
tlăi	tlʌI	**bek**	bek
suăl	suvʌl	**pâi**	pa:I
kài	ka:I	**tlawlh**	tlɔl
ít	I:t	**pen**	pe:n
thĭr	t^hi:r	**tlâng**	tlɑ:ŋ
khâwl	k^hɔl	**sawt**	sɔ:t
suak	suvʌk	**ziak**	ʒIʌk
fâwr	fɔr	**chhiár**	$\widehat{tʃ}^h$Iɑr
tuai	tuvʌI	**pùi**	puI
zâwl	ʒo:l	**sawn**	sɔn
hèl	he:l	**pêng**	pe:ŋ
zîm	ʒi:m	**vĭr**	wIr
mĕi	meI	**fing**	fIŋ
sîn	si:n	**kawlh**	kɔl
chûl	$\widehat{tʃ}$ul	**zép**	ʒe:p

APPENDIX: III

List-3

(Bisyllabic)

Half List - 1		Half List - 2	
tuàrchhel	tuvʌrʧʰel	**tármit**	tʌrmIt
sahriak	sʌʃrIɑk	**sialsuk**	sIəlsuk
reiek	rɑiek	**ramár**	rʌmɑ:r
laiking	lɑIkIŋ	**zawlnei**	ʒɔlneI
chártín	t͡ʃɑrti:n	**chhimtir**	ʧʰimti:r
ziàlzuk	ʒIɑlʒu:	**hmazil**	ʰma:ʒIl
kawrfual	kɔrfuɑl	**samṭawk**	sʌmṭrɔk
sihal	sIʰʌl	**aiéng**	ɑIeŋ
beisei	beIseI	**tukverh**	tukwerʔ
mittui	mIttuI	**satel**	sʌtel
vaivut	wɑIwut	**vaimím**	wɑImi:m
thilpek	tʰIlpek	**tuirial**	tuIrIʌl
sakei	sʌkeI	**sapthĕi**	sɑ:ptʰei
rorel	rore:l	**ruahhmi**	ruɑʔʰmI
luhlul	luʔlul	**lawngleng**	lɔŋleŋ
zarzo	ʒɑ:rʒɔ	**zaizir**	ʒəIʒIr
senhri	senʃrI	**kawlthăi**	kɔltʰeI
derhken	derʔken	**tuipui**	tuIpuI
pensil	pensIl	**hamrik**	ʰʌmri:k
bakkilh	bʌkkIlʔ	**theipui**	tʰeIpuI
vaki	waki:	**sawmli**	sɔmli:
saitual	sɑItuɑl	**chingit**	ʧIŋIt
kangṭhai	kʌŋṭrɑI	**sakhi**	sʌkʰi:
fanghmir	fʌŋʰmi:r	**dàwidim**	dɔIdIm
sahmul	sʌʰmul	**zilhhau**	ʒIlʔʰɑu