SPEECH PERCEPTION IN NOISE (SPIN) WITH KANNADA HIGH FREQUENCY WORDS: NORMATIVE DATA

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Master's Dissertation as a part of fulfillment of

Final Year M.Sc., (Audiology),

submitted to the University of Mysore, Mysore

ALL INDIA INSTITUTE OF SPEECH AND HEARING

MYSORE – 570006

May, 2005

DEDICATED TO

To Lord Almighty
&
My Ever loving family

Maa & Baba

Certificate

This is to certify that this Master's dissertation entitled **"Speech perception in noise (SPIN) with Kannada high frequency words: Normative data"** is the bonafide work done in part fulfillment of the degree of Master of Science (Audiology) of the student with register number: A0390012. 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 diploma or degree.

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This to certify that this Master's Dissertation entitled **"Speech perception in noise (SPIN) with Kannada high frequency words: Normative data"** has been under my supervision and guidance.

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DECLARATION

This is to certify that this Master's Dissertation entitled **"Speech perception in noise (SPIN) with Kannada high frequency words: Normative data"** is the result of my own study under the guidance of **Dr. Asha Yathiraj**, Reader, Department of Audiology, All India institute of Speech and Hearing, Mysore and has not been submitted earlier at any University for any other diploma or degree.

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INTRODUCTION

Understanding speech in background noise is occasionally difficult for normal hearing listeners. It has been demonstrated that sensorineural hearing impairment is connected with a loss of recognition in noise compared to normal hearing (Palva, 1955; Plomp, 1978). There is a small portion of people with normal hearing thresholds and speech recognition in quiet surroundings who have great difficulty in managing in an everyday noisy environment (dysacusis). Even though " speech in noise" tests do not provide any significant help in localizing a lesion in the hearing system (Jayaram, Baguley & Moffat, 1992), a fast and reliable test helps in predicting and assessing the benefit of amplification (Plomp, 1978; Dirks, Dubno & Morgan, 1984), in assessing job suitability and alleviating medico-legal work (Lutman, Brown & Coles, 1986).

Understanding speech in adverse conditions is an extremely important and challenging task for the human auditory system (Beattie, Barr, & Roup, 1997). During daily conversations, most people possess the ability to "tune out" interfering noises that emanate from various directions, focusing instead on signals of interest. When adverse conditions disrupt speech perception, miscommunication is usually a temporary, albeit annoying, inconvenience because most conversations offer ample opportunity to repeat words or phrases not initially understood (Beattie, 1989). The ability to understand speech in noise depends upon multiple factors such as the characteristics of the speech signal, the signal-to-noise ratio, and the listener's degree of hearing impairment. A routine hearing evaluation usually does not provide ample information about a listener's functional communication abilities.

In everyday listening conditions, there is always some noise present. The listener, however, also observes the speaker, which increases the perception of speech in noise (O'Neil, 1954; Sumby & Pollack, 1954; Erber, 1969; Sanders & Goodrich, 1971; Ludvigsen, 1973). In such conditions, the speaker tries to compensate for the noise interference by raising the level of voice in order to keep the subjective loudness of speech in noise equal to the loudness of speech in quiet (Markides, 1986).

Daily communication requires the ability to understand speech in varying degrees of noise. Normal hearing individuals do not complain about understanding speech in quiet environments, but may have some difficulty with understanding speech in noisy environments (Wilson & Strouse, 1999). It has been established that individuals with sensorineural hearing loss (SNHL) demonstrate greater difficulty understanding speech in background noise than do normal hearing individuals under the same conditions (Dubno, Dirks & Morgan, 1984). Each one of these above mentioned variables interact and play a role in determining how well one understands speech in any given environment (Nilson, Soli & Sullivan, 1994). Listeners with identical word recognition abilities in quiet can have significantly different word recognition abilities in background noise (Beattie, Barr & Roup 1997; Wilson & Strouse, 1999).

Speech is a redundant auditory signal comprised of many bits of information (Martin, 1994). Similarly, our language structure has both extrinsic and intrinsic language redundancies. The extrinsic redundancies involve information obtained from phonemes and syntax The listener possesses the intrinsic language redundancies based on their experiences with the language (Miller, Heise & Lichten, 1951).The more extrinsic and intrinsic redundancies available, the easier it becomes to understand the speech signal (Miller, Heise & Lichten, 1951). Due to speech redundancy, normal–hearing individuals can understand the signal even though it may be highly degraded, as in a crowded restaurant (Wilson & Strouse, 1999).

The redundancy of the speech signal varies depending on whether one is listening to words in isolation, listening to sentences or participating in a conversation (Festen & Plomp, 1990). Generally, it is much easier to understand longer speech signals than short ones, even when the speech is embedded in background noise. Sentences are the easiest signal to understand as they provide the listener with acoustic information, semantic and contextual cues and linguistic content. These signals provide greater redundancy. It is much easier to understand a conversation about a known subject, than single syllable words. Monosyllabic words, embedded in background noise are the most difficult speech signal to comprehend. However, due to the increased redundancy and contextual cues in sentence materials, it becomes more difficult to determine whether the listener has perceived the entire sentence or has responded to a few key words that convey the meaning of the sentence (Wilson & Strouse, 1999).

Speech-in-noise testing has what some consider an advantage over many other central tests in that no specially recorded tapes or procedures are required for administration. Only a conventional audiometer and standardized recorded monosyllabic word lists are required for administration. The clinician with the more cavalier approach may even choose to use monitored live voice. It is this ease of administration which has caused speech-in-noise testing to be one of the most used, and perhaps misused, speech tests of Central Auditory Nervous System (CANS) function. Clinicians unaccustomed and unprepared in conducting central testing often resort to this test when faced with a patient with a possible CANS disorder. Unfortunately, the testing is frequently conducted without normative data and in many cases without knowledge of the actual SN ration (i.e. identical audiometer dial settings for the speech and noise signals do not guarantee a 0 dB SN ratio measured in sound pressure level (SPL). A reasonable method for reducing the variability of speech-in-noise recognition measurements is to record the monosyllables and the white noise at the desired SN ratio on the same tape track. Additionally, by presenting both the speech and noise from a single recording, the second channel of the audiometer will be available for presenting contralateral masking, if necessary.

Though speech-in-noise tests have primarily been used in testing for the presence of an auditory processing problem, it has also gained importance as a realistic test to determine the utility of hearing aids.

Sparseness and redundancy give rise to an account of speech perception in noise based on glimpsing. Many studies have demonstrated that a single competing talker or amplitude-modulated noise is a far less effective masker than multi speaker babble or speech-shaped noise (Festen & Plomp, 1990).

Need for the study

- Individuals with high frequency hearing loss require to be tested with words primarily having high frequency speech sounds. To meet this need, specific high frequency word tests have been developed (Gardner High Frequency Word Lists, 1971; Pascoe High Frequency Test, 1975; California Consonant Test, 1977; Speech Identification Test for Hindi and Urdu Speakers, 2001; HF-KSIT, Mascarenhas, 2002). In a quiet situation some individuals with high frequency hearing loss may not display any difficulty in perceiving some of the high frequency words due to the presence of redundant cues. In order to decrease the external redundancy, noise can be introduced (Miller, Heise & Lichten, 1951).
- Speech in noise test has been developed with words covering all phonemes of the language (Egan, 1948). However, a speech in noise test, which includes only high frequency words, has not been developed.
- This test would be highly useful in selecting amplification devices for those hearing impaired individuals with the gradual sloping hearing loss, which do not depict difficulty in perceiving high frequency words in a typical test situation where noise was not used. Prior to utilizing the test on individuals with hearing impairment it is essential to get normative data. This information would enable the audiologist to know how deviant the hearing impaired individual is when compared to normals. Hence, it is not only essential to develop a high frequency speech in noise test, but also necessary to obtain normative data.

Aims of the study

The aims of the study are:

1. To develop a speech perception in noise test making use of high frequency words and restaurant noise,
2. To obtain normative data for the developed test on Kannada speaking adults,
3. To compare the norms across different signal-to-noise ratios,
4. To study the effect of gender on the developed test.

REVIEW

It has been observed that subjects with a high frequency problem perform well in quiet. In presence of noise, when tested with sentences they make use of the redundant cues. So, they need to be tested with words in the presence of noise.

The reduction of performance in an identification task with the introduction of noise has been widely documented. The most obvious effect is a shift of the articulation function to the right, a reasonable expectation based upon the masking of the signal. Aside from the effect of masking, the other factor affecting discrimination would seem to be the degree of sensorineural hearing impairment, which may exist in the listener (Tillman, Carhart & Wilbur, 1963).

The Speech in Noise (SIN) Test developed in late 1970s, by Kalikow, Stevens and Elliott (1977) was originally developed as a test of hearing impairment for speech using sentence length materials. Since the test was intended to evaluate performance in relatively realistic listening conditions, the target words were placed within sentential context, and speech babble was used as noise. Since its development, the SPIN Test has been used both for clinical evaluation of hearing impairment and for experimental psycholinguistic research (Elliott, 1995).

While using any speech perception test, it is essential to note the equivalence of the various forms. Morgan and Kamm (1981) studied the form equivalence of the ten forms of the speech perception in noise (SPIN) test. Normal hearing subjects were tested monaurally on all ten forms. Twenty-five subjects were presented the materials at 80 dB

SPL at a signal-to-babble ratio of –1 dB. An additional 25 subjects heard the materials at 30 dB SPL, at a signal-to-babble ratio of +3 dB. The data were analyzed for equivalence using a parallel test model. The results indicated that a subset of seven lists fits the equivalence model for High Predictable (HP) and Low Predictable (LP) and difference (HP – LP) scores. Additionally, analysis of list–pair data (combination of companion forms) suggested that all five lists–pairs resulted in equivalent performance.

In the following section the effect of a few factors such as age and type of hearing loss on speech-in-noise perception would be reviewed.

Effect of Age on speech-in-noise perception:

Elliot (1995) studied the performance of children aged 9 to 17 years on a test of speech intelligibility in noise sentence material with controlled word predictability. He found that the 11 and 13 year olds performed significantly poorer than 15 and 17 year olds, and this difference occurred primarily for high-predictability sentences presented at a 0 dB signal-to-babble ratio. Performance of nine-year-olds was significantly poorer than performance of 11 year olds.

Perhaps the most dramatic example concerning the need for normative data, however, is illustrated in the literature concerning speech in noise testing in children. Cohen and Keith (1976) reports that children scoring below 90% on a PBK wordlist presented in white noise (SN=0 dB) are at risk for impaired selective attention skills. In describing a group of children (mean age 9 years 8 months) considered to have auditory perceptual deficits, he reports mean PBK-in-noise scores of 61%. In striking contrast to the data of Cohen and Rupp (1983) also using PBK lists in white noise at a 0 dB SN ratio, reports mean scores for normal children in the same age range to be 39%. In other words, 9 year old child scoring 50% on the PBK-in-noise test could be considered to have a substantial auditory perceptual deficit or to be functioning better than average depending on which criteria is used.

Pichora-Fuller, Schneider and Danemen (2000) conducted a study to note, how young and old adults listen to and remember speech-in-noise. Two experiments using the materials of the Revised Speech Perception in Noise (SPIN-R) Test were conducted to investigate age-related differences in the identification and the recall of sentence-final words heard in a babble background. In experiment 1, the level of the babble was varied to determine psychometric functions (percent correct word identification as a function of S/N ratio) for presbycusics, old adults with near-normal hearing, and young normal-hearing adults, when the sentence-final words were either predictable (high context) or unpredictable (low context). Differences between the psychometric functions for high- and low-context conditions were used to show that both groups of old listeners derived more benefit from supportive context than did young listeners. In experiment 2, a working memory task was added to the SPIN task for young and old adults. Specifically after listening to and identifying the sentence-final words for a block of *n* sentences, the subjects were asked to recall the last *n* words that they had identified. Old subjects recalled fewer of the items they had perceived than did young subjects in all S/N conditions, even though there was no difference in the recall ability of the two age groups when sentences were read. Furthermore, the number of items recalled by both age groups was reduced in adverse S/N conditions. The results were interpreted as supporting a processing model in which reallocable processing resources are used to support auditory processing when listening becomes difficult either because of noise, or because of age-related deterioration in the auditory system. Because of this reallocation, these resources are unavailable to more central cognitive processes such as the storage and retrieval functions of working memory, so that ``upstream'' processing of auditory information is adversely affected.

From the above studies, it is evident that performance of speech perception in the presence of noise varies as a function of age. In children, as the age increases, the scores improve. In contrast in senior individuals, with advance in age, the scores reduce.

Effect on Type of Hearing Impairment:

Pekkarinen, Salmivalli and Suonpaa (1990), studied the effect of noise on word discrimination by subjects with impaired hearing and compared them with those with normal hearing. A comparison was made of the discrimination ability of different groups of hearing-impaired and normal-hearing subjects in noisy conditions. Four groups of subjects having a sensorineural hearing loss with various audiogram configurations, one group of subjects having a conductive hearing loss and one group of normal-hearing subjects were chosen. The tapes were recorded in quiet and in pink noise with signal-to-noise ratios of -3, -8, and -13 dB. The test subjects heard the test words monaurally via earphones. The best speech discrimination was achieved in quiet, anechoic conditions. As the noise level increased, speech discrimination decreased. Subjects with sensorineural hearing loss were more adversely affected by noise than subjects with normal hearing or with conductive hearing loss. However, at high noise levels, their speech discrimination was poorer than that of normal-hearing subjects. Persons with a high-frequency hearing loss, with a cut-off point at 1 kHz, suffered in noise similarly to those with sloping or flat hearing losses. In quiet and in moderate noise, the speech discrimination of subjects with a conductive hearing loss and subjects with normal hearing was similar, while at high noise levels, subjects with conductive hearing losses achieved better discrimination than normal-hearing subjects.

Speech perception in low-pass filtered noise in normal and hearing impaired was investigated by Stelmachowicz, Lewis and Jesteadt (1990). An adaptive procedure was used to estimate the S/N ratio for a 50% performance level in low-pass filtered noise with a range of cutoff frequencies. Data were obtained from five normal-hearing listeners at two speech levels (50 and 75 dB SPL) and four hearing–impaired listeners at one speech level (75 dB SPL). The hearing impaired listeners required a better S/N ratio than the normal listeners at either presentation level for all except the widest bandwidth, where their S/N ratios began to converge with the normal values. In addition, the S/N ratios for the hearing impaired listeners plateaued at relatively narrow bandwidths (0.75 to 2.5 kHz) compared to the normal hearing group (3.0 to 5.0 kHz). That is, the addition of high frequency components to the noise did not alter performance. These findings suggest that the hearing impaired listeners may have relied upon either low-frequency cues or prosodic cues in the perception of these test items.

Stuart and Phillips (1996) investigated word recognition in continuous and interrupted broadband noise by young normal hearing (YNH), older normal hearing (ONH), and presbycusic listeners (Older hearing impaired, OHI). Thirty-six subjects were presented with identical Northwestern University Auditory Test No. 6 stimuli at 30 dB sensation levels with reference to their respective speech reception thresholds. The speech stimuli were presented in quiet and in both competing noise conditions with signal-to-noise ratios of 10, 5, 0, -5, -10, -15, and -20 dB. It was found that in general, performance was superior in quiet, improved with increasing S/N, and was greater in the interrupted broadband noise than in the continuous broadband noise. Significant main effects of group and S/N were found in both competing noises ($p < 0.0001$). Post hoc pair wise comparisons revealed all groups performed differently, with superior performance being displayed by the YNH group followed by the ONH and OHI groups, respectively ($p < 0.05$). A significant group by S/N interaction was observed in only the interrupted noise condition ($p = 0.019$). The degree of change in word recognition performance as a function of S/N was greatest in the OHI group followed by the ONH group and the YNH group. They concluded that the group effects observed in the interrupted noise would imply that the two older groups of listeners had an auditory temporal deficit relative to the YNH listeners. The paradigm reveals the potency of the temporal processes that are responsible for the perceptual advantage (i.e., a release from masking) a listener has in interrupted competing stimulus.

Beattie, Barr and Roup (1997) studied word recognition scores for monosyllabic words in quiet and noise on normal and hearing-impaired subjects. Fifty-one normal hearing subjects were tested at 50 dB HL using signal-to-noise ratios (S/Ns) of 5, 10 and 15 dB. Thirty subjects with mild-to-moderate sensorineural hearing losses were tested in quiet and in noise at S/Ns of 10 dB and 15 dB. Monosyllabic words in a multi-talker noise were selected for testing. The mean scores for the normal-hearing subjects were

45% at the 5 dB S/N, 74% at the 10 dB S/N, and 87% at the 15 dB S/N ratio. For the hearing impaired subjects, scores were 85% in quiet, 60% at the 15 dB S/N, and 40% at the 10 dB S/N ratios. These results suggest that background noise, which is mildly disruptive for normal hearing subjects, can be highly disruptive to hearing–impaired subjects. Moreover, these findings indicate that subjects with mild-to-moderate sensorineural hearing loss, require a more favorable S/N than normal listeners to achieve comparable word recognition scores. Test-retest differences for word recognition scores revealed variability that agreed closely with predictions based on the binomial distribution of for both groups of subjects. Speech-in-noise abilities must be measured directly because regression equations revealed that speech-in-noise scores couldn't be predicted accurately from either pure tone thresholds or speech–in-quiet scores. Word recognition functions are presented from several hearing-impaired subjects and demonstrate the value of testing in noise.

McDermott and Dean (2000) studied speech perception with steeply sloping hearing loss and effects of frequency transposition. In the study six adults with a very steeply sloping high-frequency hearing loss listened to monosyllabic words in several conditions. In the first condition, their ability to identify phonemes with a signal-to-noise ratio of 6 dB was measured. Results were similar to those of normally hearing subjects listening to the same material through low-pass filters having comparable cut-off frequencies. In the remaining two conditions, four of the hearing-impaired subjects, and a control group of five normally hearing subjects, listened to speech in quiet with and without frequency transposition. The transposition lowered all speech frequencies by a factor of 0.6. Specific auditory training with transposed speech materials different from the materials used in the tests of speech perception was provided in 10 sessions, each of one hour's duration, which were scheduled at weekly intervals. Despite this training, no significant differences were found between the two conditions in these subjects' recognition of words. It is concluded that such a frequency-transposition scheme, if implemented in a wearable hearing aid, would be unlikely to benefit people with a sloping hearing impairment of this type.

The influence of hearing and age on speech recognition scores in noise in audiological patients and in the general population was examined by Barrenas and Wikstrom (2000). The objective of the study was to describe the influence of pure tone audiometry and age on the speech recognition score in noise, both in audiological patients and also in a random population sample. In a cross-sectional study, speech recognition scores (SRS), using monosyllabic words presented in a background noise were evaluated on 1895 audiological patients of both genders with normal hearing or sensorineural hearing losses. The background noise was speech weighted and presented with a signal-to-noise ratio of +4dB. In 291 participants, SRS in quiet was estimated as well. A female random population sample also was tested (N=513). The results they found were, the major predictor for the SRS in noise was high frequency hearing thresholds. If hearing was normal, age had no effect on speech recognition. Young persons with hearing loss had higher SRS in noise than older persons with the same degree of hearing loss. The difference between young and old persons became larger, the greater the hearing loss. Predictive SRS in noise with consideration taken to hearing function and age were given. SRS in noise correlated stronger with pure tone audiometry and age than SRS in quiet. Controls performed better (by 10 to 20%) than their same-aged peers with similar hearing loss. They concluded that, speech recognition tests be performed in background noise. SRS noise is a valuable tool for audiologists and audiological physicians to identify patients in need of pedagogic rehabilitation programs or further diagnostic investigations.

In general it can be observed that the hearing-impaired have a greater difficulty in perceiving in noise, when compared to normal hearing individuals. Their perception also varied depending on the level of the noise, and the type of hearing impairment.

Effect of type of noise:

Eisenberg, Dirks, and Bell (1995) studied the speech recognition in amplitude-modulated noise of listeners with normal and listeners with impaired hearing. The effect of amplitude-modulated (AM) noise on speech recognition in listeners with normal and impaired hearing was investigated in two experiments. In the first experiment nonsense syllables were presented in high-pass steady-state or AM noise to determine whether the release from masking in AM noise relative to steady-state noise was significantly different between normal-hearing and hearing-impaired subjects when the two groups listened under equivalent masker conditions. The normal-hearing subjects were tested in the experimental noise under two conditions: (a) in a spectrally shaped broadband noise that produced pure tone thresholds equivalent to those of the hearing-impaired subjects, and (b) without the spectrally shaped broadband noise. The release from masking in AM noise was significantly greater for the normal-hearing group than for either the hearing-impaired or masked normal-hearing groups. In the second experiment, normal-hearing and hearing-impaired subjects identified nonsense syllables in isolation and target words in sentences in steady-state or AM noise adjusted to approximate the spectral shape and gain of a hearing aid prescription. The release from masking was significantly less for the subjects with impaired hearing. These data suggest that hearing-impaired listeners obtain less release from masking in AM noise than do normal-hearing listeners even when both the speech and noise are presented at levels that are above threshold over much of the speech frequency range.

Pittman and Wiley (2001) studied recognition of speech produced in noise. A two-part study examined recognition of speech produced in quiet and in noise by normal hearing adults. In Part I five women produced 50 sentences consisting of an ambiguous carrier phrase followed by a unique target word. These sentences were spoken in three environments: quiet, wide band noise (WBN), and meaningful multi-talker babble (MMB). The WBN and MMB competitors were presented through insert earphones at 80 dB SPL. For each talker, the mean vocal level, long-term average speech spectra, and mean word duration were calculated for the 50 target words produced in each speaking environment. Compared to quiet, the vocal levels produced in WBN and MMB increased an average of 14.5 dB. The increase in vocal level was characterized by increased spectral energy in the high frequencies. Word duration also increased an average of 77 ms in WBN and MMB relative to the quiet condition. In Part II, the sentences produced by one of the five talkers were presented to 30 adults in the presence of multi-talker babble under two conditions. Recognition was evaluated for each condition. In the first condition, the sentences produced in quiet and in noise were presented at equal signal-to-noise ratios (SNR (E)). This served to remove the vocal level differences between the speech samples. In the second condition, the vocal level differences were preserved (SNR

(P)). For the SNR (E) condition, recognition of the speech produced in WBN and MMB was on average 15% higher than that for the speech produced in quiet. For the SNR (P) condition, recognition increased an average of 69% for these same speech samples relative to speech produced in quiet. In general, correlation analyses failed to show a direct relation between the acoustic properties measured in Part I and the recognition measures in Part II.

Interactive effects of low-pass filtering and masking noise on word recognition was studied by Scott, Green, and Stuart (2001). Word recognition in noise paradigm was employed to examine temporal resolution in individuals with simulated hearing loss. Word recognition scores were obtained for low-pass filtered speech (i.e., cutoff frequencies of 1000, 1250 and 1500 Hz) presented in continuous and interrupted noise at signal-to-noise ratios (SNRs) of -10, 0, and 10 dB. Performance improved with increasing SNR and low-pass frequency filter settings. Generally, word recognition performance was better in the interrupted noise condition than the continuous noise condition. This effect was greatest in the -10 dB SNR condition. Since the continuous/interrupted performance difference steadily declined as a function of low-pass filter cutoff frequency, these findings suggest that one factor leading to poorer speech recognition in individuals with high-frequency hearing impairment may be their dependence on low-frequency hearing channels that are inherently poorer than high-frequency channels for temporal resolution.

While some studies indicate that the type of noise used influences speech identification abilities, others are of the opinion that it does not affect speech perception.

Probably, this difference in findings between studies could be on account of differences in the noise used. In addition to the type of noise, the signal-to-noise ratio would also affect speech perception.

Effect of Signal-to-noise ratio:

The linear portion of the articulation function in noise was investigated by Cooper and Cutts (1971) using sixteen normal and fifteen sensory neural impaired subjects. NU auditory test No. 6 was presented in cafeteria noise of SNR of 4, 8 and 12 dB. It was seen that although the sensory neural group had a poorer mean, the slopes of the two groups were not significantly different, 3.57% per dB for normal and 3.47% per dB for sensory neural. The wide range of variability demonstrated by both groups indicates the importance of determining a patients discrimination potential in noise.

Stuart and Phillips (1996) investigated word recognition in continuous and interrupted broadband noise by young normal hearing (YNH), older normal hearing (ONH), and presbycusic listeners (Older hearing impaired, OHI). The speech stimuli were presented in quiet and in both competing noise conditions with signal-to-noise ratios of 10, 5, 0, -5, -10, -15, and -20 dB. It was found that in general, performance was superior in quiet, improved with increasing S/N, and was greater in the interrupted broadband noise than in the continuous broadband noise.

Hornsby and Ricketts (2001) studied the effects of compression ratio, signal-to-noise ratio, and level on speech recognition in normal-hearing listeners. This study examined the interactive effects of signal-to-noise ratio (SNR), speech presentation level, and compression ratio on consonant recognition in noise. Nine subjects with normal hearing identified CV and VC nonsense syllables in a speech-shaped noise at two SNRs (0 and +6 dB), three presentation levels (65, 80, and 95 dB SPL) and four compression ratios (1:1, 2:1, 4:1, and 6:1). Stimuli were processed through a simulated three-channel, fast-acting, wide dynamic range compression hearing aid. Consonant recognition performance decreased as compression ratio increased and presentation level increased. Interaction effects were noted between SNR and compression ratio, as well as between presentation level and compression ratio. Performance decrements due to increases in compression ratio were larger at the better (+6 dB) SNR and at the lowest (65 dB SPL) presentation level. At higher levels (95 dB SPL), such as those experienced by persons with hearing loss, increasing compression ratio did not significantly affect speech intelligibility. Similar findings have also been reported by other researchers in children as well as adults (Gengel, 1971; Finitzo-Hieber, 1978; Kamlesh, 1998; Gopi Krishna, 2003)

Effect on Context:

Wijngaarden, Steeneken and Houtgast (2002) quantified the intelligibility of speech-in-noise for non-native talkers. The intelligibility of speech pronounced by non-native talkers is generally lower than speech pronounced by native talkers, especially under adverse conditions, such as high level of background noise. The effect of foreign accent on speech intelligibility was investigated quantitatively through a series of experiments involving voices of 15 talkers, differing in language background, age of second language (L2) acquisition and experience with the target language (Dutch). Overall speech intelligibility of L2 talkers in noise was predicted with a reasonable accuracy from accent ratings by native listeners, as well as from the self–ratings for proficiency of L2 talkers. For non-native speech, unlike native speech, the intelligibility of short messages (sentences) could not be fully predicted by phoneme-based intelligibility tests. Although incorrect recognition of specific phonemes certainly occurs as a result of foreign accent, the effect of reduced phoneme recognition on the intelligibility of sentences may range from severe to virtually absent, depending on (for instance) the speech to noise ratio. Objective acoustic-phonetic analyses of accented speech were also carried out, but satisfactory overall predictions of speech intelligibility could not be obtained with relatively simple acoustic phonetic measures.

Evaluation of speech perception in noise (SPIN) was studied by Hutcherson, Dirks and Morgan (1995). The test was administered on normal hearing subjects to determine the effects of presentation level and signal-to-babble ratio on the speech perception in the noise (SPIN) test. The SPIN test contained sentences that simulate a range of contextual situations encountered in everyday speech communication. Findings from several representative patients with sensorineural hearing loss demonstrated the possible clinical utility of the test to measure the effects of context on speech discrimination test.

A comparison between the performance of normal hearing and hearing-impaired listeners using a German version of the SPIN test was carried out by Tschopp and Zust (1993). The test forms consisted of 15 sentences each with a length of five to nine syllables. The forms were constructed with either low predictable (LP) final words or high predictable (HP) final words, based upon the amount of contextual information available in the sentence. The test was performed with a background noise and used adaptive testing strategies. The proportion of HP to LP responses was compared. Normally, scores of the HP segment are higher than those of the LP segment of the test, because the increased contextual information contributes to a better understanding of the HP final words. The SPIN test results in young normally hearing listeners (n = 12), elderly normally hearing listeners (n = 13), young hearing-impaired subjects (n = 14) and elderly hearing-impaired subjects (n = 19) were reported. The most important findings were that the LP-HP difference was not dependent on the degree of peripheral hearing loss, and that no age-related effects could be demonstrated. The SPIN test results were compared with conventional speech audiometric parameters, hearing threshold levels for pure tones and self-reported hearing handicap. Low to moderate correlations were present but were not consistent across comparisons.

The influence of sentence context in the presence of noise on speech perception in young and older adults was investigated by Hutchinson (1989). The ability of young and older adults to use contextual cues to understand speech in ordinary listening situations was studied. Key word recognition scores were obtained with the Speech Perception in Noise (SPIN) test. Sentence lists contained 50 key words preceded by a high predictability (HP), low predictability (LP), or a carrier phrase (CP) context accompanied by a varying background of multi-talker babble. Comparison of the low context items Vs the number of meaningfully rich items correctly identified provided an index of the listener's ability to use contextual information in the HP sentences. The LP and CP score reflected the individual's ability to recognize items based only on the acoustic-phonetic information of the key words. Most individuals were able to take some advantage of contextual cues in everyday sentences. However, the older listeners were more adversely affected by background noise than younger listeners. For clinical utilization of the SPIN test, further research is needed to develop normative data as a function of age to make it an "age-fair" test.

Owen (1981) studied the influence of acoustical and linguistic factors on SPIN test difference score. Here, SPIN test difference scores, which was the numeric difference between items of high predictability and low predictability, were obtained from three groups of subjects to determine whether the subject's language skills influenced the size of the difference score. For this purpose the relationship between the difference score and the following variables was determined: syntactic skills, semantic skills, IQ, age, hearing loss, and signal-to-noise ratio (S/N). Results indicated that the difference scores were significantly related to the subject's hearing and the S/N ratio used in the administration of the SPIN sentences.

The contextual cues available in the signal being used, affect responses in a speech-in-noise test, is evident from the above studies. The more predictable a sentence, the higher is the score, even with noise being present.

Application of SPIN:

Studies on speech in noise have been shown to be at least marginally sensitive to a wide range of disorders of central auditory nervous system and related disorders (Dayal, Tarantino & Swisher, 1996; Chermak, Vonhof & Bendel, 1986). Elliott (1995) studied verbal auditory closure and the speech perception in noise (SPIN) Test. He concluded that, ability to utilize auditory contextual information to facilitate speech-recognition verbal auditory closure is postulated to be a specific factor or primary mental ability, separable from general intelligence or other mental functions. His paper proposes that measurement of verbal auditory closure provides useful clinical information. Since the Speech Perception in Noise (SPIN), test allows separate scores for understanding of sentences that contain contextual information and of those that do not, the SPIN Test provides a good measure of verbal auditory closure.

Kiukaanniemi and Sorri (1988) studied speech intelligibility in difficult signal/noise circumstances. In practice, subjects wearing ear protectors often give contradictory statements about the possible distorting effects of ear protectors. The authors tried to simulate some difficult background circumstances by arranging five different signal/ background noise combinations (five S/N ratios). Speech discrimination tests made in these circumstances with and without ear protectors could reflect the real capacity to understand orders or messages in difficult hearing situations. Fifty two Finnish-speaking conscripts with normal hearing from 18 to 24 years age were selected to participate in the test on a day without any noisy training duties. The test words in the Finnish speech discrimination test in combination with corresponding white noise were produced by equipment consisting of a high quality tape recorder, an audiometer, an amplifier and loud speakers. The test were performed individually in free field in a sound proof room in the Hearing Centre of the University Central Hospital of Oulu. The subjects listened to the test words with all the S/N ratios (S/N = 60/70, 55/70, 65/70, 60/75 and 65/75 dB (A)] with and without ear protectors. At the signal/noise ratios 60/70 and 60/75 dB the words were perceived relatively poorly with and without hearing protectors. At the signal/noise levels of 65/70 and 65/75 dB the protectors turned out to produce highly significantly better word discrimination. At the signal/noise level of 55/70 dB the discrimination was very poor in both cases but significantly better without ear protectors.

Speech in noise has been recommended while prescribing hearing aids. Gopi Krishna (2003) used the high frequency words and sentence lists, for hearing aid selection for individuals with sloping high frequency hearing loss at two SNRs (10 and 5 dB). Findings of the study implies that either the word or the sentence subtests, in the presence of noise (10 or 5 dB) could be used equally effectively in selecting hearing aids for steep and precipitous sloping hearing loss. Hence, it can be seen that Speech in Noise tests have varied applications. These include testing for the presence of auditory processing problem, checking the utilities of EPDs and in the prescription of hearing aids.

While high frequency word lists have been used to test for the utility of the hearing aids to a limited extent, norms are not available. The norms are required to make judgments regarding the perceptual deviances seen in the hearing impaired individuals.

METHOD

The aim of the present study was to develop normative data for speech perception in noise with high frequency Kannada words as stimuli for adult Kannada speakers. The study was done in two stages.

Stage I: The development of the test material

Stage II: Administration of the test on normal hearing individuals

Stage I: Development of the test material

The material used for the study was obtained from the High Frequency Kannada Speech Identification Test (HF-KSIT) developed by Mascarenhas (2002). In the present study, two of the word sub lists were used and either of the two was randomized and used as a third list. These two word lists were reported to be equally difficult by Mascarenhas (2002). Each word subtest contained 25 words having equal distribution of high frequency consonants. Using the Cool Edit software the material was developed. The recorded version of HF- KSIT was copied and pasted on one track while restaurant noise was recorded on a second track. It was ensured that the noise and speech signal were of equal loudness, by normalizing the signals. Prior to each list, a 1000 Hz calibration tone was recorded in each word list, and was used to adjust the VU meter of the audiometer to zero.

Stage II: Administration of the test

Subjects

Forty Kannada speaking adults (twenty female and twenty male) aged between 18-28 years were tested. The average age of the normally hearing subjects was 21.4 years. Listeners satisfied the following criteria: (a) bilateral pure tone air and bone conduction thresholds of less than or equal to 15 dB hearing level (HL; ANSI, 1996) for the octave frequencies 250 to 8000 Hz (b) normal bilateral immittance results; (d) air-bone gap of less than 10 dB HL; (c) no documented history of otitis media and (f) no apparent articulatory abnormality and (g) should be literate.

Equipment and Speech Material

The subjects were tested using a Madsen electronics orbiter OB 922 clinical audiometer using TDH-39 headphones with MX41/AR cushions and B 71 bone vibrator. The audiometer was calibrated according to ANSI, 1996 standards. Immittance testing was done using GSI Tympstar. Speech material consisted of words from the High Frequency Kannada Sentence Identification Test by (Mascarenhas, 2002). The material developed for the study was played using the Cool Edit software. The signals from the two tracks were rooted from a Pentium IV computer to the tape and auxiliary input of a clinical audiometer (Orbiter OB 922). It was ensured that signals from the two tracks were sent to two different channels but to the same ear. The intensity of the two tracks was manipulated using the attenuator dial of the audiometer. The two-word lists, each consisting of 25 words were routed from the computer to a clinical audiometer (Orbiter OB 922) and presented to each participant through an MX41/AR earphone.

Environment

The testing was done in a sound treated double room, with the ambient noise levels within permissible limits as recommended by ANSI, 1991 (S3.1-1991) (cited in Wilber, 1994).

Procedure

a) For subject selection:

Initially all subjects were tested for puretone thresholds. The testing was done for the frequencies 250 Hz to 8000 Hz for air-conduction and 250 Hz to 4000 Hz for bone-conduction. All the subjects were also tested for normal middle ear function using the tympanometry and acoustic reflex test.

b) For obtaining speech-in-noise scores

The individuals who passed the subject selection criteria were recruited for obtaining speech identification in presence of noise. The subjects were initially instructed that they would be hearing speech and noise in one ear. They were asked to attend to the speech signals and write down what they heard. Subjects were also informed that they could guess the test items in case they were not very clear. The subjects were tested 40 dB above their puretone average (average of thresholds of speech frequencies 500 Hz, 1000 Hz and 2000 Hz) (ASHA, 1997, cited in Rupp & Stockdell, 1980). The subjects were tested either in the right ear or in the left ear. Half of the subjects were tested in the right ear while the other half was tested in the left ear. The noise levels were varied so as to present the signals at 0, +10 and +20 SNR. All subjects initially heard the test material at 0 dB SNR followed by +10 and +20 dB SNR. The subjects heard the same list at 0 dB SNR condition and +20 conditions. A different list was heard in the +10 dB SNR condition. Half of the subjects were tested with list I in the first and last noise condition while the other half of the subjects heard list II. Thus, it was ensured that all subjects were tested in the three SNR conditions.

Scoring

The responses obtained from the subjects were scored as right or wrong. Each correct word was given a score of one and a wrong word was given a score of zero. The responses obtained from the subjects were statistically analyzed keeping in mind the objectives of the study.

RESULTS AND DISCUSSION

The data obtained from the normal population was analyzed using SPSS 10.0 version. Analysis of variance (ANOVA) was done for:

1) Effect of SNR

2) Effect of list and

3) Effect of gender on Speech identification scores in different SNR

(1) Effect of SNR

An initial analysis using analysis of variance (ANOVA) showed a significant effect of SNR on speech identification scores (SIS) for both the lists {($F(2, 57) = 102.38$, $p < 0.05$) for List I and ($F(2, 57) = 191.435$, $p < 0.05$) for List II}. The effect of SNR across lists was analyzed using Tukey's post hoc test. It revealed that there is a significant effect of SNR at 0, 10 and 20 dB for both Lists I and II (Table 1). Figure 1 depicts the mean speech identification scores and standard deviations at different SNRs, across lists and gender. It suggests that 20 dB SNR gave the best SIS, where as the 0 dB SNR gave the worst SIS, with the SIS at 10 dB SNR being inbetween. This was seen for both the Lists I and II.

Table 1: Effect of SNRs on SIS

SNR (dB)	'p'- value	
	List I	List II
0 vs. 10	0.000 *	0.000 *
10 vs. 20	0.007 *	0.000 *
0 vs. 20	0.000 *	0.000 *

*. Significant at 0.01 levels.

Initial analysis revealed that five of the words in each of the lists were extremely difficult for the normal hearing subjects in 0 SNR condition. 72% to 5% of the subjects found these words difficult in the 0 SNR condition in both the lists. Hence, it was decided to drop words that had more than 55% of the subjects not identifying them. The words that were included in list I and list II for the final analysis is given in the appendix A.

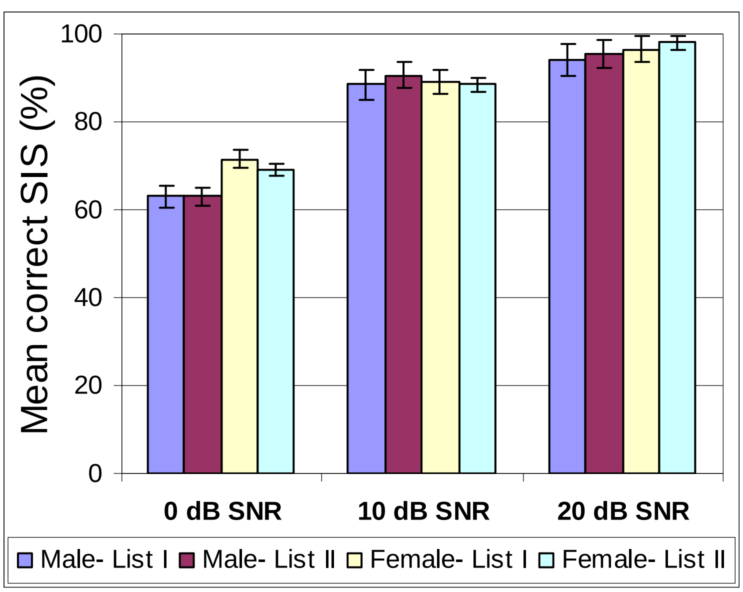

Figure 1: The mean speech identification scores. Error bars show +/- 1 SD

The results of the present study concur with the documentation of the reduced discrimination performance in noise of the normal hearing listeners. Earlier studies (Young & Herbert, 1970; Keith & Talis, 1970, 1972; Olsen, Noffsinger & Kurdziel, 1975) also reported an identification decrement in the presence of noise in normal hearing adults. The reason why speech identification scores decreased with decrease in SNR is due to the greater masking effect that takes place (Nelson, Schoder & Wojtczak, 2001). On account of the masking, the external redundancy present in the speech signal decreases making it difficult for the subject to perceive the signal.

2) Effect of list

To check if the two lists that were used in the present study were equal, a one-way ANOVA was carried out. It showed no statistically significant difference between lists at different SNR's. Table 2 shows the summary of this analysis. No significant difference was noted at both the 0.01 and 0.05 levels.

Table 2: Mean, SD and F- values for list I and II

SNR (dB)	List I		List II		'F' value
	Mean+	SD	Mean+	SD	
0	13.45	1.79	13.20	1.24	0.263
10	17.75	1.12	17.25	1.02	0.196
20	19.05	0.76	19.32	0.81	1.45

+ Maximum score = 20

The analysis that was done, prior to the deletion of the five words from the two lists showed that the lists were not equal. The lists were found to be unequal in the lower SNR conditions (0 dB SNR and 10dB SNR). However, at the higher SNR condition (20 dB SNR) the lists were found to be equal. In contrast Mascarenhas (2002) had reported that these two lists were equal. While Mascarenhas (2002) has carried out the study in quiet, the present study utilized noise as a masker. This could have attributed to the difference in findings of the two studies. In the presence of lower SNR's, the intelligibility of certain words probably dropped making it difficult for the subjects to perceive them. On deletion of these words the inequality of two lists disappeared. Hence, it is recommended that while using HF-KSIT in the presence of noise, the word included in the two lists given in appendix A, be used and not the entire original list.

3) Effect of gender

One-way ANOVA was performed to see the effects of gender on speech identification scores at different SNRs for both the lists. The mean, SD and 'F' value is shown in Table 3. For both list I and II, at 0 dB SNR, there was a significant difference between SIS of males and females. At 0 dB SNR, the SIS in females was higher than that of males. However, no effect of gender could be observed at 10 and 20 dB SNR, for both the lists.

Table 3: Mean, SD and F values for effect of gender

List	SNR (dB)	Male		Female		'F'- value
		Mean+	SD	Mean+	SD	
I	0	12.6	1.96	14.3	1.16	5.594 *
	10	17.7	1.25	17.8	1.03	0.038
	20	18.8	0.79	17.3	0.67	2.32
II	0	12.6	0.96	13.8	1.22	5.89 *
	10	18.1	1.19	17.7	0.82	0.758
	20	19.1	0.99	19.6	0.51	1.991

* Significant at 0.05 level; + Maximum score = 20

Such gender difference, in the presence of noise, has been reported by Gatehouse (1994). According to Gatehouse, males needed more intensity to "just follow" speech in quite as well as in noise compared to females. Similar findings have also been reported by Govil (2002). He too reported that, in the presence of noise, females in three different age groups (6-8 years, 8-10 years, and 18-30 years) obtained significantly higher scores than males. He utilized an SNR of 10 dB.

A possible reason for the above finding, as to why females obtain higher scores in the presence of noise, could be because of females being able to use both the hemispheres for processing compared to males. This inference is based on an investigation by Kanasaku, Yamaura and Kitazawa (2000), who reported that females use the posterior temporal lobe more bilaterally during linguistic processing of global structures compared to males.

Hence, it is recommended that while using speech in noise test the response of a client should be compared to the norms of a particular sex. This should be specially done at lower SNR's.

Tables 4 and 5 indicate that with a decrease in SNR, the number of subjects who could not perceive specific words was high. For the 0 dB SNR, depending on the word, 5% to 50% of the subjects did not perceive the stimulus. No word was perceived by all the subjects in this noise condition. List I had words that were not perceived by a larger number of subjects, while in list II, this variability was less.

The number of subjects who did not perceive words correctly was lesser for the 10 dB SNR and 20 dB SNR condition. Based on these findings, it is recommended that while testing hearing impaired individuals in the presence of noise, the 0 dB SNR condition should not be used. This condition is difficult even for normal hearing individuals.

Table 4: Percentage of subject in which error seen for specific words in list I

Words	% of subjects in which error seen for specific words		
	0 dB SNR	10 dB SNR	20 dB SNR
Ili	25%	-	-
se:risi	50%	10%	10%
HoTTe	45%	-	5%
vitʃa:ra	20%	5%	-
tʃikki	35%	15%	10%
SiTTu	50%	30%	10%
tʃakra	35%	5%	-
Hasivu	50%	20%	10%
Sikku	35%	10%	20%
tʃiTTe	30%	-	-
Tale	35%	10%	10%
ko:ti	55%	10%	-
KuLLi	35%	25%	-
tʃamatʃa	10%	10%	-
ʃile	10%	10%	-
sarije	30%	20%	-
sa:lu	45%	25%	20%
Irali	15%	10%	5%
Iruve	10%	-	-
Katte	5%	15%	-

Table 5: Percentage of subject in which error seen for specific words in list II

Words	% of subjects in which error seen for specific words		
	0 dB SNR	10 dB SNR	20 dB SNR
rutʃI	35%	-	5%
kuLLa	20%	-	-
koLe	20%	5%	-
sose	25%	5%	5%
sukha	25%	5%	5%
taTTe	30%	20%	15%
ko:Te	45%	20%	5%
kelasa	35%	15%	-
i:ruLLi	50%	-	5%
avaLu	45%	-	-
iTTe	30%	20%	5%
aLate	40%	20%	-
ka:Lu	25%	5%	-
e:Lu	30%	5%	-
ʃa:le	35%	-	-
sari	20%	5%	-
aʃTu	30%	-	-
hatʃtʃu	20%	-	5%
tʃillare	50%	-	-
ta:Lu	40%	10%	15%

From the above data analysis it may be concluded that:

1. The material developed (HF-KSIT with a background competition of restaurant noise) may be used to check the perception of individuals in difficult listening conditions.
2. With the decrease in SNR, the speech identification scores decreased. This was seen for both list I and list II that was used in the present study.
3. List I and II were found to be equal after deletion of five words from each list, that were difficult for the majority of the subjects to perceive.
4. Males and females performed equally well when an SNR of 20 dB was used. However, when the SNR was reduced to 0 dB SNR, females out-performed the males.
5. The two word subtest of HF-KSIT can be used to evaluate speech in noise performance provided the list be modified as given in appendix A.
6. It is recommended that while testing hearing impaired individuals, the 0 dB SNR condition should not be used, as normal hearing individuals also found this condition to be too difficult.

SUMMARY AND CONCLUSION

Daily communication requires the ability to understand speech in varying degrees of noise. Normal hearing individuals do not complain about understanding speech in quiet environments, but may have some difficulty with understanding speech in noisy environments (Wilson & Strouse, 1999). It has been established that individuals with sensorineural hearing loss (SNHL) demonstrate greater difficulty understanding speech in background noise than do normal hearing individuals under the same conditions (Dubno, Dirks & Morgan, 1984).

The present study was undertaken to develop a speech perception in noise test making use of high frequency words and restaurant noise and obtain norms for the same on Kannada speaking adults. The effect of SNR and gender was studied. The material of the study was developed using word subtest of HF-KSIT developed by Mascarenhas (2002) and restaurant noise. One track of the software program Cool Edit pro had the above word list while another track had the restaurant noise. The test material was administered on 40 normal hearing adults. They were tested using three different SNR's i.e., 0, 10 and 20 dB SNR.

Analysis of the data was done using ANOVA. The analysis revealed the following:

1. The material developed (HF-KSIT with a background competition of restaurant noise) may be used to check the perception of individuals in difficult listening conditions.

2. With the decrease in SNR, the speech identification scores decreased. This was seen for both list I and list II that was used in the present study.
3. List I and II were found to be equal after deletion of five words from each list, that were difficult for the majority of the subjects to perceive.
4. Males and females performed equally well when an SNR of 20 dB was used. However, when the SNR was reduced to 0 dB SNR, females out-performed the males.
5. The two word subtest of HF-KSIT can be used to evaluate speech in noise performance provided the list be modified as given in appendix A.
6. It is recommended that while testing hearing impaired individuals, the 0 dB SNR condition should not be used, as normal hearing individuals also found this condition to be too difficult.

IMPLICATIONS:

1) The present speech-in-noise would be useful in evaluating individuals with gradual hearing loss, who complain of auditory perception problem but do not demonstrate having a problem with routine speech tests.
2) It would be useful in selecting amplification devices for individuals with gradual sloping hearing loss.

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APPENDIX-A

Words Included in Speech-in-Noise tests for High Frequency Kannada Words.

List I	List II
Ili	rutʃI
se:risi	kuLLa
HoTTe	koLe
vitʃa:ra	sose
tʃikki	sukha
SiTTu	taTTe
tʃakra	ko:Te
Hasivu	kelasa
Sikku	i:ruLLi
tʃiTTe	avaLu
Tale	iTTe
ko:ti	aLate
KuLLi	ka:Lu
tʃamatʃa	e:Lu
ʃile	ʃa:le
sarije	sari
sa:lu	aʃTu
Irali	hatʃtʃu
Iruve	tʃillare
Katte	ta:Lu