Monaural versus Binaural Hearing : Speech Recognition and Perceived Ease of Listening in Noise

Register No-M9912

This Independent Project submitted as part fulfilment
for the First Year M.Sc., (Speech and Hearing),
submitted to the University of Mysore, Mysore.

ALL INDIA INSTITUTE OF SPEECH AND HEARING

MYSORE 570006

MAY 2000

Dedicated to the

ALMIGHTY, GOD

CERTIFICATE

This is to certify that this Independent Project entitled : Monaural versus Binaural Hearing : Speech Recognition and Perceived Ease of Listening in Noise is the bonafide work in part fulfilment for the degree of Master of science (Speech and Hearing) of the student with Register NO.M9912.

Mysore
May, 2000

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CERTIFICATE

This is to certify that this Independent Project entitled : Monaural versus Binaural Hearing : Speech Recognition and Perceived Ease of Listening in Noise has been prepared under my supervision and guidance.

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DECLARATION

This Independent Project entitled: *Monaural versus Binaurai Hearing : Speech Recognition and Perceived Ease of Listening in Noise* is the result of my own study under the guidance of Dr.K.Rajalakshmi, Lecturer in Audiology, Deparmtent 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.

Mysore
May, 2000

Reg. No.M9912

ACKNOWLEDGEMENTS

To Rajalakshmi Ma'am, my teacher and guide, thank you ever so much for your infinite patience, valuable suggestions and encouragement, without which, this work would never have been materialized.

I am grateful to **Dr.(Miss)S.Nikam,** Ex-Director, All India Institute of Speech and Hearing, Mysore for granting me permission to carryout mis study.

I thank **Dr.M. Jayaram,** Director, All India Institute of Speech and Hearing, Mysore.

I thank **Venkatesan Sir** and **Acharya Sir** for readily taking time off their schedule to patiently guide me with the statistical procedures.

Special thanks to all my **subjects** for their extreme cooperation without which, this study would never have been possible.

Amma, Appa, Your confidence in me is amazing, which I fail to have in myself. I hope I live upto your expectations.

Karthik, thanks yaar, for telling me again and again that I can do it

For innumerable reasons and for just being there, when I needed them, helping me in their own ways, A BIG thanks to my **friends and classmates....** and
To all the fun and crazy times which seems to roll in when we are together.

To **Vrusha, Vidya** my buddies forever, for constantly reinforcing me and pumping energy into me, whom I consider my long distance mentors.

Vasanthi and **Aral,** Thanx for all your encouragement and support,

Heartful thanks to **Rajalakshmi Akka** for your understanding, encourgement and giving my work,a beautiful shape.

Above **all, I** thank the **Almighty** for giving me the courage and strength to complete this project

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"God gave man two ears but only one mouth so that he might hear twice as much as he speaks"

- *Epictetus the Stoic.*

The wisdom of the "Almighty" was also referred to by Harris (1965) when he asserted that our creator would not "have simply hung a second ear on our heads purely as a mechanical safety factor in a chancy world".

It may well be that this attitude expresses deep theological convictions but it does very little to throw light on the advantages of binaural interaction" (Markides, 1977).

Hearing is based on the processing of information received through two ears. Binaural hearing is based on the ability of the total hearing system to detect two different signals, analyze their differences and perceive a single auditory image. A listener's ability to perceive and organise his auditory environment depends partly on the use of two ears and the resulting neural interactions that occur between the binaural signals as they progress through the auditory pathways.

Binaural hearing occurs when there is a balance between the two ears, as in normally hearing individuals. In individuals with hearing loss, this balance between the two ears is disturbed and hence binaural hearing is precluded.

Monaural (involving one ear only) listening is also possible. In normally hearing individuals monaural listening can be brought about; by occluding one of the ears (artificially induced by earplugs).

During the past 40 years, substantial progress has been made in the study of binaural interactions in normal listeners. These are a number of psychoacoustic effects which are dependent on the use of two ears. The perceptual advantages attributed to this binaural arrangement, given by Konkle and Schwartz (1981) include :

- an improvement in the speech recognition ability under adverse listening conditions, often referred to as the "cocktail party phenomena".

- a reduction in the effects of unpleasant background noise or reverberation, frequently termed the "squelch effect" or "koenig effect".

- enhanced sound localization.

- an avoidance or reduction of the head shadow effect that occurs when the head is positioned between the source of a primary stimulus and the aided ear, especially in a background of noise.

Langford (1970) has summarized the clinical and research observations and proposed five potential advantages of binaural amplifications:

- better sound localization,
- increased speech discrimination in noise
- greater ease of listening
- better spatial balance, and
- improved sound quality.

The hearing-impaired exhibit deficits in binaural psychoacoustic processes as they do in monaural psychoacoustic processes. The monaural changes are the more marked : elevated detection thresholds, poor frequency discrimination and resolution, impaired temporal integration and resolution and so on; the less obvious binaural impairments can have serious effects on performance. In a two dimensional, non-reverberant world, language competence and performance would be unaffected by impaired binaural processes. But in the real world, hearing-impaired people exhibit great difficulties with the localization of sound and in listening to speech in noisy or reverberant conditions (Bamford and Saunders, 1994).

Information on the effects of unilateral hearing (monaural hearing) on aspects of auditory perception can come from two sources. First from studies on normally hearing listeners, who are rendered monoaural either by presenting stimuli via one earphone only or in the sound field, by attenuating the input to one ear by means of an earplug and/or earmuffs; all studies of binaural interactions in normal listeners employ such comparison conditions in order to quantify and 'elucidate' the nature of the binaural effects. Secondly from studies, fewer in number, which have directly examined the performance of subjects with unilateral hearing losses on tasks known to involve binaural interactions (Durlach, et al. 1981).

The traditional contention that unilateral hearing loss is a minimal problem (Newby, 1958; Northern and Downs, 1978) has not been supported by recent studies. Lags in academic performance (Sarff, 1981; Blair et al. 1985) as well as problems in reading, spelling and arithmetic (Boyd, 1974) have been associated with unilateral hearing loss in children. Quigley and Thomure (1968) have reported language delay in school-age children with slight unilateral hearing-impairments. Children with unilateral hearing losses have a higher rate of grade repetition and need for academic support services than their normally hearing peers (Bess and Tharpe, 1986; Oyler et al. 1988; Flexor, 1995). Oyler et al. (1988) also reported that children with unilateral hearing-impairment exhibited difficulty with comprehension of word meaning, attention, story telling, responsibility, completion of assignments, and ability to adapt to new situations. Though, most of these items would not be considered auditory learning problem per se, but are factors that probably would influence a child's academic success.

Giolas and Wark (1967) reported that most frequent communication problems identified by individuals with unilateral hearing-impairments include the following :

- Difficulty understanding or hearing speech originating from the impaired side when the good ear is receiving a competing message or noise.

- Difficulty understanding speech under quiet and noisy condition regardless of the position of the sound source.

- Difficulty understanding speech originating from the impaired side even when the normal ear is not receiving competing signal.

Giolas and Wark (1967) further noted that their sample of subjects with unilateral hearing-impairment reported feelings of embarassment, annoyance, confusion and helplessness.

Assessment of hearing for puretones provides valuable information regarding sensitivity but limited information concerning receptive auditory communication ability. More over investigations of puretone sensitivity and speech understanding have shown no clear cut relationship between these two measures. There appears no satisfactory means of accurately predicting speech understanding ability from puretone results (Young and Gibbons, 1962; Elliot, 1963; Harris, 1965; Marshall and Bacon, 1981).

In an effort towards external validation of scores of speech recognition tasks, a number of researchers have attempted to correlate scores on self-assessment scales and quantify the extent of perceived hearing handicap experienced by hearing-impaired listeners (Anderson, 1990).

Studies on self assessment of hearing handicap or perceived handicap show that even individuals with monaural, mild or/and moderate hearing-impairment perceived themselves as having severe communication difficulties and viewed themselves as having a far greater handicap than that was reflected in the traditional audiometric measures (Newman et al. 1991; Benett, 1989; Rosenbaum, 1976).

It is likely that many of the problems experienced by children and adults with unilateral hearing losses are directly related to the objective disadvantages imposed by hearing with only one ear.

It is also possible that some of the problems develop as a function of subjective listening problems imposed by hearing with only one ear.

By inference monaural hearing (unilateral hearing loss) should result in decreases in those aspects of listening which have been associated with binaural advantage.

Though the objective advantages of binaural listening or the objective disadvantages associated with hearing with only one ear have been researched a lot, unfortunately the subjective effects of unilateral hearing loss mainly of the mild degree have not been thoroughly investigated.

The purpose of the current study was to evaluate and compare the subjects performance on sentence repetition in noise with the subjective variable of "perceived ease of listening" in unilateral listening verses binaural listening conditions. The objective variable of word recognition was also evaluated.

To explore the above variables, listening was performed under conditions of unimpeded binaural listening (BIN) and simulated hearing loss (Monaural listening; Monaural near and monaural far).

A preliminary attempt was made to determine if unilateral mild hearing loss imposed considerable listening difficulty in less than optimum conditions, such as in the presence of noise. The information obtained may provide implications for the audiological rehabilitation of the group with unilateral mild hearing loss in terms of the need to consider initiation of rehabilitative intervention, when the individual first begins to notice difficulty and determine candidacy for use of amplification, which cannot be predicted purely from the puretone averages.

REVIEW OF LITERATURE

A listener's ability to perceive and organize his auditory environment depends partly on the use of two ears and the resulting neural interactions that occur between the binaural signals as they progress through the auditory pathways. Binaural hearing is thus based on the ability of the total hearing system to detect two different signals, analyze their differences and perceive a single auditory image.

Unilateral hearing loss refers to the case where one ear exhibits puretone detection thresholds which are within normal limits, while thresholds in the other ear are elevated.

Tasks which involve binaurality and on which performance is therefore likely to suffer when there is a unilateral hearing loss, can be summed under the following headings : binaural summation, binaural release from masking, head shadow effect and localization.

Binaural Summation

Experimental research has shown that when two ears are equated for hearing sensitivity, normal listeners observe binaural gains for both pure tones and speech stimuli, that is, a binaural threshold for two ears equated is better than thresholds for either ear alone by approximately 3 dB.

Binaural summation also has been shown when stimuli are presented at suprathreshold intensities. Hirsh (1950) was among the first investigators to report that binaurally presented stimuli were about 6 dB louder than monaural signals at an intensity level 35 dB above threshold. Subsequently, Reynolds and Stevens (1960) have indicated that this loudness advantage increased to 10 dB when stimuli were presented at intensities 90 dB above threshold.

Whereas a 3 dB advantage in threshold loudness perception may appear insignificant to a normal ear because the intensity of conversational speech is well above threshold levels, individuals with hearing impairment often do not enjoy the same advantage. Hence, a 3 dB improvement may indeed be substantial for a hearing-impaired person who often is forced to listen to conversational speech at or near threshold level.

This concept has been illustrated by Konkle and Schwartz (1981) by the two performance intensity (P-I) functions, one for monaural listening and other for binaural listening in the following figure.

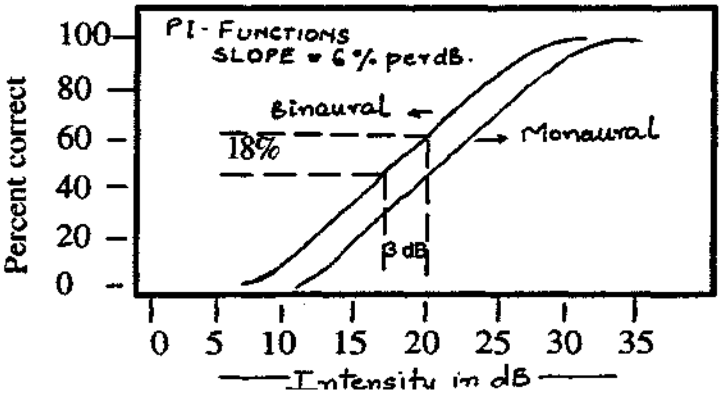


Fig.l: Word recognition performance-intensity (PI) functions for monaural and binaural listening, *(SOURCE :Konkle and Schwartz,* 1981)

The linear portion of each function rises at a rate of 6 % per dB, and the two functions are separated approximately by 3 dB. Hence, binaural listening can result in a word recognition score that is approximately 18% better than the monaural score obtained at the same intensity. Konkle and Schwartz also reported a 30 percent improvement in speech intelligibility for continuous discourse, because of the above advantage. The difference between monaural and binaural listening would be magnified for continuous discourse, since the linear portion of the slope for such stimuli was much steeper, about 12 % per dB.

Binaural Release From Masting

Signal detectability under binaural listening conditions has been widely investigated in experiments that have independently manipulated the interaural parameters by a masker and a to be detected signal (Durlach, 1972). In general, if different interaural manipulations are imposed on the masker and the signal, the signal becomes more detectable than if the same manipulation is imposed on both masker and signal or if masker and signal are presented to only one ear. This improvement in signal detectability under binaural listening conditions is known as binaural release from masking and the difference in thresholds is called the binaural masking level difference (BMLD). This binaural release from masking has been demonstrated for complex tones, clicks and speech sounds as well as for puretones. Studies of BMLD in patients with unilateral hearing losses have shown in general less release from masking, compared to patients with symmetrical hearing losses and normally hearing listeners (Durlach et al. 1981).

The release from masking phenomenon, studied in the laboratory with headphones is the basis for a real world phenomenon known as the "cocktail party effect". This effect refers to the ability of a normal listener to attend to one conversation in the midst of a room full of "masking" conversation. A normal listener can easily appreciate the power of the effect by occluding one ear in this type of situation and noting the increased difficulty in attending to a particular signal conversation. The cocktail party phenomenon is essentially a binaural release from masking since having two ears yields an interaural time difference (ITD) for the signal conversation that is different from the ITD for the masker conversations, the differing ITD's are a result, of course of the different spatial locations of signal and masker.

Studies utilizing normal hearing subjects have revealed that speech recognition in noise improves for both binaural stimulation over monaural listening, even if the monaural condition is such that the ear is favourably positioned with regard to the primary signal.

Carhart (1965) found a binaural advantage over monaural near listening of 3 dB for 50 percent discrimination of words in competing sentences for normally hearing subjects, listening binaurally and listening monaurally with one ear occluded. This is the sound field equivalent of BMLD and Carhart called it the "squelch effect". A similar study by McKeith and Coles (1971) showed a squelch effect of between 0 to 4 dB. A maximum binaural advantage of 18 dB in the presence of noise tended to occur when the primary speech signal and the competing noise were produced at direct opposite sides of the head (McKeith and Coles, 1971).

Moncur and Dirks (1967) demonstrated that binaural discrimination was superior to monaural discrimination under various reverberation conditions, concluding that the far ear plays an important role in contributing to binaural superiority.

Head Shadow Effect

When the head intervenes between a sound source and a listeners ear, the signal from the sound source will be more intense at the ear nearest to the source (the near ear), and less intense at the ear farthest from the source (the far ear). Studies have reported differences of approximately 6.4 dB between the near ear and far ear spondaic word thresholds for normal hearing listeners when the signal source was located 45 degree from the midline of the head (Tillman et al. 1963; Olsen, 1965).

The head shadow effect has been conceptualized in the following figure by Konkle and Schwartz (1981).

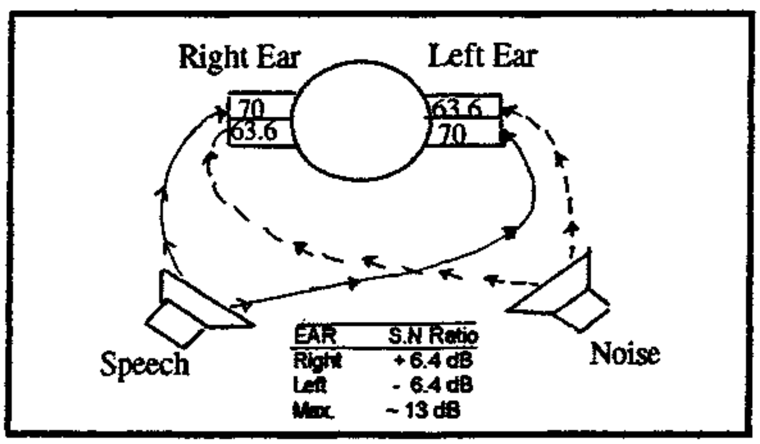


Fig.2: Illustration of the head shadow effect for speech and noise sources showing the approxiamte 13 dB signal-to-noise (S/N) ratio. (SOURCE: KONKLE and SCHWARTZ,1981).

As depicted in the figure-2, while a 70 dB signal may reach the near ear without attenuation, it is only about 63.6 dB intense at the far ear. In a listening condition, where a primary signal at 70 dB comes from a loudspeaker 45° to the right of midline and competing signal (noise) is produced at the same intensity from a loudspeaker located 45° to the left of midline, the primary signal at the right ear will be +6.4 dB more intense than the primary signal at the left ear, or an unfavourable -6.4 dB signal-to-noise ratio. Hence the maximum difference between the signal-to-noise ratio is about 13 dB.

It is important to emphasize that unfavourable effects of head shadow are minimized during binaural listening because one of the two ears is always positioned to the side of the primary signal. Whenever the primary signal is located so that the active ear is nearest to the source, the addition of a second ear results in an approximate 3 dB release from masking. In case of unilateral hearing impairment, the addition of a second ear combines the effects of squelch and head shadow so that an approximate 14 to 16 dB reduction in masking is realized (Konkle and Schwartz, 1981). MacKeith and Coles (1971) in a study consisting of normal listeners rendered monaural, found head shadow effects in terms of change in speech to noise ratio for 50% discrimination of upto 16 dB. In conditions where the (normally hearing) subjects were rendered only partly monaural, the same effect ranged from 2-9 dB.

Thus, the unilateral listener has marked difficulties when bis good ear is on the far side of his head in isolation to the unwanted signal source. Ofcourse, he could move to a favourable position, but there are circumstances (in the classroom, the theater, a committee meeting etc.) where this may not always be as easy as it may seem.

Localization

Localization refers to the ability to judge the direction and distance of a sound source. Experiments have confirmed that use of interaural time and intensity differences as primary cues for localizations of sounds in the horizontal plane (Stevens and Newman, 1936; Sandel et al. 1955). For puretone stimuli, it has been shown that the primary cues for low frequencies is the interaural time difference (TTD) while the primary cue for high frequencies is the interaural intensity difference (ITD) (Mills, 1960). This so called duplex theory of sound localization applies only to tonal stimuli; for more complex stimuli, such as speech or noise, it has been shown that ITD's as well as ITD's provide useful information (Henning, 1974).

In any case, a monaural listener is deprived of both the ITD as well as ITD cues available and must rely on the less informative cues related to pinna effects and head movements in order to localize sounds in the horizontal plane. Durlach et al. (1981) reviewed the published studies and despite difficulties in comparison and interpretation of data concluded that general localization and performance is (i) indeed degraded by unilateral hearing loss and bilateral asymmetry, (ii) degraded more by middle ear disorders and much more by auditory nerve lesions than by cochlear impairments and (iii) not easily predicted on the basis of audiograms.

In summary, there is ample evidence available to demonstrate that binaural listening is superior to monaural listening. As a listening condition becomes more adverse such as with the introduction of background noise and/or reverberation the binaural advantage gains added importance.

Effect of Noise on Speech Recognition

Acceptable noise levels for enclosures used for various types of activities were developed by Beraneket al. (1971) and recently revised by Beranek (1989) in the form of preferred noise criteria" (PNC) curves represent the tolerance of average listeners with normal hearing to noise at frequencies between 31.5 Hz and 8 kHz.

Excellent listening condition, such as in conceit halls, require that noise levels, expressed in terms of A weighted averages, be no greater than 20 dB. For good listening conditions in auditoriums and drama theaters the background noise levels should not exceed 45 dB. Noise levels in shops, offices and computer rooms, with normally operating equipment should not exceed 60 dB. High noise levels, as they were found in many factories, are unacceptable from a communication stand point even if safety standards are not violated. Such noise conditions are often tolerated because significant noise reduction might be too costly or even impossible.

When an individual speaks in the presence of noise than some parts of the speech might be obscured by the noise and becomes inaudible or "masked". The masking effect of noise depends on various parameters of the noise (a) the long term average spectrum, (b) the intensity fluctuation over time, and (c) the average intensity relative to the intensity of speech. Masking is most effective by a noise which has the same long term spectrum.

The overall effects of noise on speech perception can be inferred from signal-to-noise (S/N) ratio expressed in dB. Speech recognition scores are generally high when the S/N is high and low when the S/N is low.

The adult listener with unilateral hearing impairment is confronted with a variety of complicated listening situations that can interfere with ease of listening and speech recognition in quiet and noise. Similarly, children may also encounter difficult listening conditions that can affect the receptive aspects of communication. If such listening difficulties are confronted during the early childhood years, it seems plausible to assume that communication and/or educational problems may also ensue.

Ambient classroom noise levels are an important factor to consider relative to the possible effects of unilateral hearing loss on young children. In addition to the noise, classrooms are often too reverberant. When reverberation is high, the binaural listener has a definitive advantage over the unilateral listener, particularly when the normal ear is farthest from the primary signal.

McCartney (1974) examined speech recognition skills both in quiet and noise in children with true monaural hearing loss, artificially imposed loss and normal hearing. The Goldman-Fristoe-Woodcock test was administered in the quiet condition and the word intelligibility by picture identification (WIPI) test was used in the noise environment. In the quiet condition, each subject took two word recognition test, one to the near ear and one to the far ear. In the noise situation, four specific testing situations were used; signal and noise from the same loudspeaker (near ear and far ear) and signal and noise separated into two loudspeakers (near ear and far ear). The results showed essentially no differences between groups in the quiet condition. In the near ear noise conditions, no differences were found across groups for both the non-separated and separated test arrangements. In the far ear conditions, however, the normal hearers performed markedly better than the subjects with monaural hearing loss.

Nabelek and Pickett (1974a) studied the reception of consonants with normal hearing subjects in a sound treated classroom, at reverberation times $T \simeq 0.3$ and 0.6 sec, to compare binaural and monaural reception, with and without hearing aids, in the presence of an impulse noise and a quasisteady noise. For the monaural condition, one ear was plugged by a rubber ear plug, which provided 25-45 dB attenuation for frequencies from 125 to 8000 Hz as measured by Bekesy puretone audiometry comparing hearing thresholds with and without the ear plug. In order to achieve total exclusion for the ear, in addition to the ear plug, a broad-band random noise, quite different from the babble or the impulsive noise, was delivered by an earphone at a level of 82 dB, which was just sufficient to ensure that the loudest speech or noise was inaudible in the plugged ear. The consonants were spoken in words embedded in a rapidly spoken carrier phrase.

It was found that, the binaural gain at short reverberation, with unaided listening, was 5 dB in the presence of the babble and 4 dB in the presence of the impulsive noise. The introduction of hearing aids and the increase in reverberation each caused the binaural gain to decrease to 3 dB. The results, indicated that the best reception could be obtained by a binaural listener in a room with short reverberation. With prolonged reverberation., impulse noise was more detrimental than quasi-steady noise.

Finitzo-Hieber and Tillman (1978) studied the effect of reverberation and noise on monosyllabic discrimination for normal hearing children and a group of hearing-impaired children with mild-to-moderate hearing losses. Three reverberation times (0, 0.4 and 0.2s) and four listening conditions (quiet; +12, +6 and 0 dB s/n ratios) were evaluated. Data were collected in an anechoic room under monaural conditions; the normal hearing children wore a single earmuff and the hearing-impaired children wore an ear level hearing aid. The results showed that, increased reverberation time caused a decrease in word discrimination for both normal hearing and hearing impaired group, and the combination of reverberation and noise had a greater effect on hearing-impaired children than on normal hearing children. Discrimination of speech by the normal hearing children did not decrease significantly in the 0.4s reverberation condition (quiet), although significant decreases did occur in the 1.2 reverberation condition. The combined effect of reverberation and noise did, however effect the normal hearing children even at the, rather short 0.4s reverberation time.

The normal hearing children in the above study seemed to be affected more by reverberation than were a group of normal hearing adults tested under similar conditions by Crum (1974). Cram (1974) found little decrease in speech discrimination by adults in a 1.2s reverberation condition (quiet). The difference between the two studies was that the subjects were tested binaurally by Crum, while the children in Finitzo-Hieber and Tillman study were tested monaurally.

Ross and Giolas (1980) investigated the effect of different classroom listening conditions on speech recognition in a group of 13 minimally hearing-impaired children. The mean word recognition scores for groups under usual listening conditions in the classroom were 20,32 and 91% for the aided hearing-impaired, minimal hearing-impaired and minimal hearing children respectively. The poor scores for the children with monaural hearing loss indicates that children with even very mild hearing losses can experience difficulty understanding speech in the classroom.

Newman and Hochberg (1983) studied the children's perception of speech under reverberant conditions typical of modem classrooms. Recordings of nonsense syllables (VCV construction) were presented to groups of children aged 5, 7, 9, 11 and 13 years and young adults under monaural (reverberation time 0.6s) and binaural (reverberation times ~ 0, 0.4 and 0.6s) conditions of reverberations. Newman and Hochberg found that phoneme identification scores in reverberant conditions improved with increasing age and decreased with increased reverberation time. The children's performance in reverberant conditions did not reach asymptote untill age 13. Furthermore, binaural performance was consistently better than monaural performance for all age groups with the 5 year olds showing the largest binaural advantage.

Boney and Bess (1984) examined the effects of noise and reverberation on the speech recognition (monosyllabic and sentence stimuli) of normal hearing children and a group with minimal hearing loss. Speech recognition was assessed in quiet, noise alone, reverberation, alone, and noise and reverberation combined (s/n = +6 dB; T =0.85 sec). The results indicated that normal hearers performed significantly better than the minimally hearing-impaired group under most listening conditions for both types of stimuli and as the listening condition worsened, word recognition decreased for both groups. Also, noise and reverberation appeared to induce a synergestic effect on the performance of both groups.

IMPACT OF HEARING LOSS

It is evident that speech recognition is reduced in the presence of noise for the unilaterally hearing impaired listener, even when the loss is of a mild degree. When the ability to separate the desired signal from background is impaired, there is a breakdown in the perceptual ability. This inability to differentiate the primary signal from a background of noise may be a factor in the difficulties faced by some learning disabled or language delayed children (Bess and Tharpe, 1986).

Goetzinger (1962) suggested that weakness in the auditory identification of speech sounds was one of the causal factors in poor reading skills.

In another study, Sarff (1981) examined the educational status of children with minimal hearing loss. An audiometric screening of 601 children revealed that *32.19c* exhibited minimal hearing loss, puretone average (PTA) of 15 dB or greater with no thresholds exceeding 40 dB HL; or failure to respond to 6 of 14 test frequencies (250 to 8 kHz) at 10 dB HL but PTA within 40 dB HL. It was found that 57.2% of the population had an academic deficit coexisting with the minimal impairment. In addition, Sarff also indicated that many school-age children with unilateral high frequency hearing loss (> 2000 Hz) were showing deficits in educational performance.

To investigate the effect of minimal hearing loss on academic/ intellectual performance, Burner and Mouw (1982) carried out two studies. The first study involved correlating group data and audiometric test results obtained on elementary school students from three sites in Southern Illinois. The second study compared the performance of 2 groups of learning disabled students on individual intelligence measures. One group had a minimal hearing loss, while the other had no detectable loss, nor had evidence of a loss during their developmental history.

The results indicated that minimal hearing loss was related to poor academic achievement and to lower scores on group IQ measures. The learning disabled children with a minimal hearing loss had significantly lower verbal performance and full scale IQ scores than did their hearing counterparts. The IQ was determined using the WISC-R.

Blair et al. (1985) studied the effects of mild sensorineural hearing loss on academic performance of young school-age children. Their study measured the academic performance of children with mild sensori-neural hearing loss of 20-45 dB by comparing them with a normal hearing control group. 24 pairs of children in the I to TV grades were compared. A 2-way analysis of variance was used to compare the achievement scores from the Iowa test of Basic Skills administered to the two groups. The results indicated statistical significance on some subjects of the I and IV grade student scores. The standard mean score was almost always poor than that of the normal hearing control group in every grade.

Flexor (1995) reported that there are about 39.5 million school children in the U.S. and approximately 8 million of them have the some type and degree of hearing loss. But only 1 % of them were being served. The children not served, identified or underserved were those with minimal, mild or unilateral (stable/fluctuating) hearing impairments.

Flexor (1995) investigated the kinds of problems they face. It was found that these children had several problems, which included the following:

1) Hearing feint/distant speech (more than 25% of the classroom instruction could be missed).

2) Hearing subtle conversational cues that could cause a child to react inappropriately.

3) Following fast-paced verbal exchange.

4) Hearing the final word sound distinctions that denote plurality, tense, possessives etc.

5) Because of the extra effort needed to hear, the child may appear immature and become fatigued.

6) Thus, the premise of the educational system is undermined.

Hearing loss gives an "acoustic filter effect" i.e. it distorts, smears, or eliminates incoming sounds, especially sounds from a distance even at a short distance.

Self-Assessment of Hearing Handicap:

One purpose of speech recognition testing is to predict the impact of hearing loss on performance in everyday listening situation since they offer the clinician means of assessing communication function in a quasi-systematic manner (Olsen and Matkin, 1984).

In an effort towards external validation of scores of speech recognition tasks, a number of researches have attempted to correlate scores on self-assessment scales and quantify the extent of perceived hearing handicap experienced by hearing- impaired listeners (Anderson, 1990).

The premise underlying these investigations was the incomplete relationship between hearing impairment data and handicap as measured using self-assessment techniques. Clinically, it was apparent that individuals with minimal/mild hearing loss often experience significant handicap whereas persons with moderate hearing loss may not perceive themselves as being handicapped. Data on the relation between word recognition ability and perceivedhandicap confirm that scores on speech measures account for little of the variability in the perception of communication difficulties and in the perception of psychological ramifications of hearing loss.

Rowland et al. (1985) made a comparison of speech recognition in noise and subjective communication assessment. He used quiet and babble (SPIN test) conditions and items from a self assessment scale concerned with communication ability in quiet and noise (understanding speech section of the hearing performance inventory (HPI). For the hearing impaired group, correlations between speech recognition and ratings on the self-assessment items were poor, suggesting that performance measured with these tests have only a weak relationship.

Bennett (1989) fit 98 patients with amplification who had hearing levels of less than 20 dB HL at 500 and 1 kHz and less than

35 dB HL at 2 kHz. After a 30 day trial period, 92% of the patients elected to purchase the hearing aids. At the end of 6 months, 85% of the patients considered the hearing aids, a worthwhile investment

Newman et al. (1991) also illustrated the imperfect relationship between handicap and impairment by administering a self-report handicap measure in a pre-fitting and post-fitting paradigm to a sample of individuals with hearing losses ranging from mild to severe. Subjects with hearing loss of greater than 40 dB HL demonstrated mean pre-fitting and post-fitting scores similar to those of subjects with hearing losses of less than 40 dB HL. The magnitude of hearing aid benefit, thus was not affected by the degree of impairment.

Newman et al. (1997) investigated the impact of mild hearing loss on an individual's psychosocial function and communication ability in daily life as measured by the hearing handicapped inventory for adults (HHIA). Self-perceived hearing handicap was assessed in a sample of 63 patients having either unilaterally normal hearing or mild hearing loss bilaterally (puretone average less than 40 dB HL).

Large intrasubject variability in responses to HHIA confirmed observations that reactions to mild hearing loss vary greatly among patients. The individual differences in responses highlight the importance of quantifying the perceived communication and psychological handicap which cannot be determined from the audiogram alone. An item examination of responses to the HHIA revealed, items relating to feeling frustrated, upset, and left out,had the three highest endorsement rates for the subjects with unilateral normal hearing. More than 50% of the sample reported problems in the presence of background noise (eg. parties, restaurant, visiting) and when using a television or radio.

Schow et al. (1989) found a systematic relationship between handicap/disability as measured by the self-assessment of communication (SAC) and the various puretone groups. Based on the low frequency (500 Hz and/or 1000 Hz) subjects were classified into borderline, normal, slight, mild, moderate or severe categories and then the mean of the better ear thresholds at 2000 and 4000 Hz were used to establish configurations of flat, gradual (falling) or sharp (drop).

People within the same degree of loss groups systematically showed more handicap as they progress from flat to gradual to sharp configurations. Mean handicap scores dropped out of the normal SAC range when 1000 and 2000 Hz exceeded 25 to 30 dB and when 4000 Hz exceeds 40 to 45 dB suggesting that even individuals with slight and mild hearing losses exhibited handicap. Handicap/disability ratings were also found to be systematically related to the use of hearing aids. When a group of hearing aid users was categorized into puretone groups (PTGs) based on unaided thresholds in the better ear, it was seen that 87% of all users, are distributed in the groups involving, borderline normal, slight and mild hearing loss.

It is likely that many of the problems experienced by children and adults with unilateral hearing losses are directly related to the objective disadvantages imposed by hearing with only one ear as outlined through the factors leading to binaural advantage. It is also possible that some of the problems develop as a function of subjective listening problems imposed by hearing with only one ear.

Libby (1980) reported the following subjective advantages of binaural listening, with respect to hearing aid use:

- increased ease of listening,
- increased loudness
- increased spatial balance
- improved sound quality and
- increased success in difficult listening situations.

Feuerstein (1992) studied the variables of word recognition, perceived ease of listening and attentional effort for speech in noise (SPIN) under binaural and two simulated monaural conditions. The two monaural conditions differed as a function of unoccluded ear orientation to the primary signal (monaural near and monaural far). Word recognition was assessed by having the subjects to repeat the last word in each SPIN sentence while they simultaneously performed a secondary task designed to evaluate the amount of attentional effort being applied to listening. A modified magnitude estimation of ease of listening was generated by the subjects after each listening condition.

Results indicated that ease of listening ratings and word recognition scores were significantly poorer during monaural listening and significantly affected by ear orientation to the speech signal. Attentional effort was not significantly affected by changing from binaural to monaural near listening, but was significantly poorer in the monaural far condition than in either of the other listening conditions. There was significant correlations between ease of listening ratings and word recognition, but no correlation between attentional effort and either ease of listening or word recognition.

From the review of literature, it is evident that individuals with unilateral mild to moderate degree of hearing loss experience great difficulty in communication in the presence of noise, although performance may be adequate in quiet condition.

Though the objective disadvantages associated with hearing with only one ear have been researched a lot, meagre information is available on the subjective listening problems imposed by hearing with only one ear.

The current study was undertaken to evaluate and compare the subjects performance on sentence repetition in noise with the subjective variable of perceived ease of listening in unilateral versus binaural listening condition. The objective variable of word recognition in noise was also evaluated.

METHODOLOGY

The present study was undertaken to evaluate the subjects performance on sentence repetition and word recognition in noise as well as perceived ease of listening in unilateral listening versus binaural listening condition.

The methodology used for the study may be divided into the following:

SUBJECTS :

The subjects for the study were 30 normal young adults in the age range of 18 to 30 years, 15 of whom were males and 15 were females.

Subject selection criteria

The subjects selected for the study had:

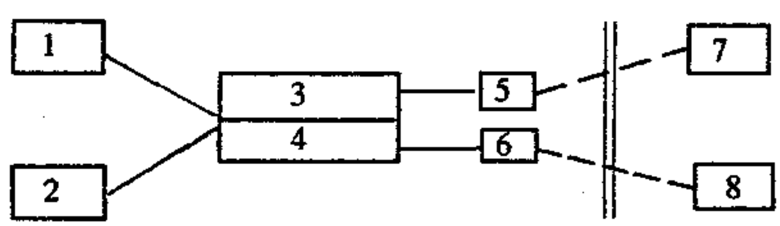
(i) no known history of hearing loss.
(ii) no chronic otologic problems
(iii) puretone thresholds less than 15 dB in both ears in the frequency range of 250 Hz - 8000 Hz in air conduction and 250 Hz - 4000 Hz in bone conduction
(iv) no middle ear pathology as shown by immittance audiometry.

INSTRUMENTATION

The data was collected using monitored live voice (MLV) on a dual channel audiometer (Madsen OB 822). The output of the audiometer for puretone testing, was fed to earphone TDH 39 housed in circumaural ear cushions (MX 41-AR). For speech testing, the output of the audiometer was amplified through Madsen PA 5010 power amplifier and fed to loudspeakers placed at 45 degree azimuth at a distance of one meterfrom the subject. The noise (speech babble) was presented Philips AW606 taperecorder through the auxiliary input of the audiometer. The response of the subject was monitored through the talk back system of the audiometer.

The calibration of frequency and intensity for puretones and speech was done to confirm to ANSI, 1989 specifications-Calibration of frequency and intensity was also done for BC vibrator.

A block diagram of the instrumentation used to present the stimuli for testing is depicted in the figure 3.



1- Microphone; 2- Tapercorder; 3&4: 2 channels of audiometer;
5&6 - Power amplifier; 7&8 - Loudspeaker

Fig.3: Block diagram of the instrumentation used for presentation of stimuli for testing

Test environment

The data were collected in a sound treated two room set-up. The ambient noise level in the room was measured and it was confirmed to the recommendations specified by the ANSI, 1991.

Test stimuli

The test stimuli used in the study consisted of lists of sentences used in daily conversation as well as paired words. The sentences were randomly selected from a standardized competing sentence test in Kannada (Hemalatha, 1982). The sentences were of similar length and contained approximately equal number of words and syllables. Three sets of sentences consisting of 10 sentences each was used in the study (Appendix la). Paired words developed in All India Institute of Speech and Hearing were used in the study. The paired words consisted of three sets, each consisting often paired words (Appendix lb).

Procedure

Initially, puretone thresholds were found out for the frequencies 250 Hz, 500 Hz, 1 kHz, 2 kHz, 4 kHz and 8 kHz under TDH-39 earphones using the modified Hughson and Westlake Procedure (Carhart and Jerger, 1959).

Listening was performed under conditions of unimpeded binaural listening (BIN) and simulated unilateral hearing loss i.e. monaural listening (M).

To simulate a hearing loss, for the monaural listening tasks, an EAR brand acoustical earplug was inserted into the ear of each subject The choice of the ear plug was based on a comparative study which found no statistically significant difference in the attenuation characteristics of indigenous and imported ear protective devices (Ami Mathew, 1994).

The subjects puretone thresholds were again obtained after occluding the ear with the earplug, in order to find the amount of hearing loss simulated.

The monaural conditions were referred to as either monaural near (MN); in which the unoccluded ear was oriented towards the loudspeaker from which the primary stimuli were presented; or monaural far (MF) in which the unoccluded ear was oriented towards the loudspeaker from which the background noise was presented. Changes between monaural conditions were accomplished by changing the signal source arrangement at the loudspeakers.

To maintain consistent intrasubject occlusion, the earplug was not removed between the monaural conditions. Counterbalancing was used to assure that one half of the subject group had the right ear occluded while the other half had the left ear occluded.

In the binaural condition, the subject did not wear the ear plug. The signal source arrangement (ear orientation) for BIN for each subject was always identical to that used with that subject for the monaural near (MN) listening condition.

In order to offset learning and fatigue artifacts, the BIN condition was counterbalanced by subject group such that for half the subjects, the BIN condition occurred before the monaural condition, while for the other half, the BIN conditions occurred after the monaural conditions (MN and MF).

The primary stimuli (sentences or paired words) was presented through one loudspeaker at an intensity level of 45 dB HL, while the noise (speech babble) was presented through the other at 50 dB HL such that the signal to noise ratio at the location equivalent to the centre of the listener's head was -5 dB.

Dependent variables

Perceived ease of listening:

The sentence list to be presented in a particular listening condition was randomly selected. The subjects were asked to repeat each sentence after the experimenter. Perceived ease of listening was assessed in each listening condition (BIN, MN and MF conditions), after completion of the entire sentence list, using a simple rating scale.

The subjects were instructed as follows:

You are going to hear some sentences through one loudspeaker and noise through the other. You have to repeat each sentence after hearing the sentence. At the end of the list, you have to judge the ease with which you listened to the sentence on a scale from two-ten. Number ten means it was very easy while two means, it was very difficult Do not pay attention to the loudness of the sentences or the noiseness. Remember: Judge only the ease of listening. By ease, I mean, how easy it was for you to listen to the sentences.

Table-1: Rating scale for perceived ease of listening judgements.

2 -	Very difficult, need to strain in order to listen
4 -	Difficult, need to concentrate
6 -	OK, just fine, need to pay attention.
8-	Easy
10 -	Very easy

Word recognition

Randomly selected paired word list were presented in each listening situation. Word recognition was assessed by having the subject repeat the paired words, and guessing was encouraged if the subject was unsure of the words.

Scoring

The data collected from each subject was tabulated as under :

Name

Age/Gender

Ear occluded: Right/Left

Frequency (Hz) --->	250	500	1k	2k	4k	8k
Air conduction thresholds dBHL						
Unoccluded : Right ear						
Left ear						
Occluded ear: Right/Left ear						

	MN	MF	BIN
Sentence repetition score	/10	/10	/10
Subject's rating on scale			
Paired word recognition score	/10	/10	/10

Responses were scored as either one or zero. Score of one was given if the sentence or the paired word was repeated correctly, while all errors and no responses were scored as zero. No repetitions were provided by the experimenter.

Analysis

The raw data was subjected to statistical analysis where the mean, range and standard deviation was calculated. The paired t-test was used to find out significance of difference between the listening conditions for the dependent variables. The Pearson's product moment correlation was used to find the correlation between the subjects performance on sentence repetition and the rating score in each listening condition.

RESULTS AND DISCUSSION

The aims of the current study were :

- to evaluate the subjects performance on sentence repetition in noise, perceived ease of listening and word recognition in noise under conditions of binaural listening (BIN) and simulated hearing loss (Monaural listening; monaural near, MN and monaural far, MF).

- to determine if the subject's performance on sentence repetition correlated with that of the perceived ease of listening in the three listening conditions.

The raw data collected from the subjects were tabulated and subjected to statistical analysis. Statistical analysis was done with the help of the computer based statistical package : NCSS i.e. Number crunching statistical software, version 5X series (Hintze, 1982-92).

Table-2: Mean, standard deviation and range of the raised thresholds from 250 Hz to 8 kHz after insertion of the ear plug.

Frequency (Hz)	250	500	1000	2000	4000	8000
Mean (dB HL)	28	31	34	37	42	48
Standard Deviation	3.37	3.8	2.03	3.37	3.37	3.37

Table-2 depicts, the mean, standard deviation and range of the raised thresholds from 250 Hz to 8000 Hz, brought about by the insertion of the earplug. It is evident that the insertion of the earplug into the subjects ear resulted in a simulation of a gradually sloping conductive hearing loss of approximately 34 dB HL in the speech frequencies of 500 Hz, 1000 Hz and 2000 Hz. The above results are similar to the approximate 30 dB HL loss reported by Feuerstein (1992).

The mean, standard deviation and range for the variables of sentence repetition, perceived ease of listening ratings and word recognition in the three listening conditions (binaural: BIN; monaural near: MN; monaural far: MF) were tabulated.

Table-3: Mean, standard deviation and range of sentence repetition scores in the three listening conditions.

Listening condition	Mean	Standard deviation	Range
MN	7.77	1.07	6-10
MF	5.93	1.33	4-9
BIN	8.87	0.73	8-10

Table-4: Mean, standard deviation, range of the paired word recognition scores in the three listening conditions.

Listening condition	Mean	SD	Range
MN	8.7	.79	7-10
MF	7.5	.94	6-9
BIN	9.4	.62	8-10

The mean values in table 3 and table 4 show that the performance of subjects, both in terms of sentence repetition and paired word recognition, at an S/N ratio of -5 was found to be poorest in the most unfavourable listening condition, i.e. the 'Monaural Far' condition. The performance improved in the monaural near and binaural listening conditions, the binaural condition being the best. In other words, the performance of subjects, in the presence of noise tended to decrease from the binaural condition to the monaural listening conditions. This shows that an individual with mild unilateral hearing loss finds it more difficult to communicate in adverse listening conditions or at low signal to noise values especially when the primary signal was directed to the impaired ear. Similar findings have been reported in various studies (McCartney, 1974; Nabelek and Pickett, 1974a; Finetzo-Hieber and Tinman, 1978; Ross and Giolas, 1980; Feuerstein, 1992; Flexor, 1995).

Table-5: Mean, standard deviation, range of the perceived ease of listening ratings in the three listening condition.

Listening condition	Mean	SD	Range
MN	7.67	1.67	6-10
MF	5.0	1.8	2-8
BIN	9.13	1.01	8-10

The mean values of perceived ease of listening ratings in table 5 shows that BIN listening condition was judged on an average to be the easiest, MN listening was judged to be next easy, followed by MF listening condition. The wide range in the rating values indicate the variability in the subjects responses. It was observed that six out of thirty subjects rated MN listening condition similar to the BIN listening condition i.e. very easy. Though MF condition was always rated as poorer than the MN and BIN conditions, the ratings of the MF condition ranged from a score of eight (easy) to a score of two (very difficult), but never was rated as ten (very easy).

It is reasonable to assume that perception of ease is related to performance, or at least to perceived performance. In less than optimal auditory situation, such as in the presence of noise, a subject may report easy listening if performance was not affected (or not perceived as having been affected). It is therefore likely that perceived ease is impacted by other variables. Thus the individual variability in the ratings of perceived ease of listening could be attributed to extra audiologic factors such as perceived performance, attentional effort, personality of the subject etc.

Large intrasubject variability in self-assessment scales of handicap have been reported, lending support to the clinical observation that individual's react differently to similar audiometric configuration (Newman, et al. 1997).

Table-6: Mean, SD and t-test scores for the variables, sentence repetition, perceived ease of listening and paired word recognition among the three listening conditions.

	Sentence repetition			Perceived ease of listening			Paired Word recognition		
	Mean	SD	t-value	Mean	SD	t-value	Mean	SD	t-valu
BIN-MN									
BIN	8.87	0.73	4.64*	9.13	1.01	14.12*	9.4	.62	3.44*
MN	7.77	1.07		7.67	1.67		8.7	79	
BIN-MF									
BIN	8.87	0.73	10.65*	9.13	1.01	10.97*	9.4	.62	9.24*
MF	5.93	1.33		5	1.8		7.5	.93	
MN-MF									
MN	7.77	1.07	5.86*	7.67	1.67	6.96*	8.7	.79	6.34
MF	5.93	1.33		5	1.8		7.5	.93	

*-P<0.01;VHS

The paired t-test for dependent meausres were applied to assess the differences among the specific listening conditions. Significant difference was found between BIN and monaural listening (BIN versus MN and BIN versus MF) as well as between the two monaural conditions (MN versus MF) for all the dependent variables, namely, sentence repetition, perceived ease of listening and word recognition. The above results are in consanance with those of Feuerstein (1992).

Table-7: Pearson's product moment correlation coefficients between sentence repetition scores and perceived ease of listening rating in the three listening condition.

Listening condition	Correlation coefficient 'r'
MN	0.57
MF	0.46
BIN	0.51

The pearson's product moment correlation coefficient values from table-7 indicate a significant and positive correlation between the sentence repetition scores and the perceived ease of listning ratings in each of the listening conditions. It seems reasonable to suspect that the reduction in perceived ease of listening was somewhat influenced by listener's awareness of decreasing ability to understand speech. Therefore, it is likely that a perception of performance influenced the subjects ratings.

Even though, the current study was done under conditions of simulated conductive loss, there is applicability to clinical population, for adults and children with a unilateral mild hearing loss might be expected to encounter listening difficulty similar to that experienced by the subjects in this study in at least some situations.

Decreases, would be expected in speech recognition ability in the presence of noise, even with the better ear oriented towards the speaker. Marked difficulty would result for speech originating from the side of the affected ear. Children, in adverse listening conditions such as those in a classroom, might be expected to also experience frustration, due to perceived difficulty (reduced ease) in listening. Behaviourally, this could result in signs of boredom, decreased attention or "acting out" in the class.

It is therefore important to recognize the impact of mild unilateral conductive hearing loss on both the subjective and objective listening and to take steps to minimize them whenever possible.

The individual variability in the response to listening in unfavourable conditions highlights the importance of probing into the subjective listening factors such as "ease of listening" in order to facilitate appropriate intervention. The mild unilateral hearing impaired adults should be considered candidates for audiologic rehabilitation including appropriate counselling regarding communication strategies and the option to evaluate the potential benefit from amplification.

SUMMARY AND CONCLUSION

Monaural hearing (unilateral hearing loss) results in decreases in those aspects of listening which have been associated with binaural advantage. The difficulties experienced by children and adults with unilateral hearing loss could develop as a function of subjective listening problems imposed by hearing with only one ear.

An experimental study was conducted to evaluate and compare the subject's performance on sentence repetition in noise with the subjective variable of perceived ease of listening in unilateral listening versus binaural listening conditions. The objective variable of word recognition in noise was also evaluated. To explore the above variables, listening was performed under conditions of unimpeded binaural listening (BIN) and two simulated monaural listening conditions (Monaural near and Monaural far).

Thirty Kannada speaking, normal hearing adults within the age range of 18 to 30 years participated in the study. The stimuli consisted of sentences used in everyday conversation, randomly selected from a competing sentence test (Hemalatha, 1982) and paired words developed in Kannada, at the All India Institute of Speech and Hearing. The stimuli was presented at a signal to noise ratio of -5 dB.

The subjects performance in terms of repetition of sentences and paired words was scored and recorded in each listening condition. Perceived ease of listening was assessed for each listening condition by using a simple rating scale ranging from two to ten, where ten was defined as very easy and two as very difficult

The data collected was subjected to statistical analysis. Results showed significant differences between listening conditions for all the dependent variables. Subjects performance, (in terms of sentence repetition and word recognition) as well as perceived ease of listening ratings were poorer in the monaural far condition, and improved in monaural near and binaural listening condition. High intrasubject variability was seen in the ratings of the monaural far condition. The subjects performance on sentence repetition correlated with the perceived ease of listening in all the three listening conditions.

Even though, the current study was done under conditions of simulated hearing loss, applicability to clinical population exists. Adults and children with unilateral mild hearing impairment would be expected to face listening difficulty similar to that experienced by the subjects in the study. In adverse listening conditions, individuals with mild unilateral hearing loss might be expected to face marked difficulty for speech originating from the side of the affected ear.

The individual variability in the subjective response to listening in the unfavourable listening condition (MF condition) highlights the importance of probing the subjective listening factors in order to facilitate appropriate audiological intervention.

Suggestions for further Research

- The study can be carried out with different signal to noise ratios.

- The study can be replicated with persons with mild unilateral sensorineural hearing losses. Because of expected functional differences in the processing of suprathreshold sounds, the impact of mild sensorineural hearing loss may be somewhat different than that of conductive problems.

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APPENDIX I(a)

List of sentences

Set 1

1. ವಿದ್ಯಾರ್ಥಿಗಳು ಬೋರ್ಡ್ ಮೇಲೆ ಬರೀತಾರೆ.
   vid̪jart̪ʰigaɭu boːrɖ meːle barit̪aːre.
2. ಶೋಭ ಕೆಂಪು ಲಂಗ ಹಾಕ್ಕೊಂಡಿದಾಳೆ.
   ʃoːbʰa kempu laŋga haːkunɖid̪aːɭe.
3. ಕಮಲನ ತೋಟದಲ್ಲಿ ಮಲ್ಲಿಗೆ ಗಿಡ ಇದೆ.
   Kamalana t̪oːʈad̪aɭɭi mallige giɖa id̪e.
4. ಬೆಕ್ಕು ಮನೆ ಮೇಲೆ ಓಡ್ತಾ ಇದೆ.
   bekku mane meɭe oɖʌt̪aː id̪e.
5. ನಮ್ಮ ತಾಯಿ ಕೆಲಸ ಮಾಡ್ತಾರೆ.
   namma t̪ai kelasa maːɖʌt̪aːre.
6. ಮೇಷ್ಟ್ರು ದಿನಾ ಸ್ಕೂಲಿಗೆ ಹೋಗ್ತಾರೆ.
   meːʃʈru d̪ina skuːlige hoːgt̪aːre.
7. ಹಡಗಿನಲ್ಲಿ ಊರಿಂದ ಊರಿಗೆ ಹೋಗ್ತೀವಿ.
   haɖaginalli uːrind̪a uːrige hoːgt̪ive.
8. ನಮ್ಮ ಮನೆ ಹತ್ತಿರ ಮಾರ್ಕೆಟ್ ಇದೆ.
   namma mane hat̪t̪ira maːrket id̪e.
9. ರಾಜು ಮನೆಗೆ ಊಟಕ್ಕೆ ಹೋಗ್ತಾನೆ.
   raːdʒu manege uːʈakke hogt̪aːne.
10. ನಮ್ಮ ತಾಯಿ ಮನೆಗೆ ಬಂದಿದ್ದಾರೆ.
    namma t̪aːi manege band̪id̪aːre.

Set 2

1. ಗೋಪಿ ಹತ್ತಿರ ದುಡ್ಡು ಇಲ್ಲ.
   go:pi hat̪ira d̪uḍḍu i:lla.
2. ರವಿ ರಾಮಾಯಣ ಓದ್ತಾನೆ.
   ravi ra:ma:jʌna o t̪a:ne.
3. ನಾನು ಶನಿವಾರ ದೇವಸ್ಥಾನಕ್ಕೆ ಹೋಗಿದ್ದೆ.
   na:nu ʃaniva:ra d̪evast̪a:nakke ho:gid̪d̪e.
4. ಲೀಲ ಹಸಿರು ಸೀರೆ ಉಟ್ಕೊಂಡಿದಾಳೆ.
   li:la hasiru si:re uṭkonḍit̪ale.
5. ಸುರೇಶ ಚಿತ್ರ ನೋಡ್ತಾನೆ.
   sureʃa tʃit̪ra noḍt̪a:ne.
6. ನಮ್ಮ ನಾಯಿ ತುಂಬಾ ಚಿನ್ನಾಗಿದೆ.
   namma na:ji t̪umba tʃʰannagid̪e.
7. ಹುಡುಗರು ಆಟ ಆಡ್ತಿದಾರೆ.
   huḍugaru a:ṭa a:ḍt̪id̪a:re.
8. ಈ ರಸ್ತೇಲಿ ವಾಹನಗಳ ಓಡಾಟ ಜಾಸ್ತಿ.
   i: rast̪eli vahanagala o:ḍa:ta dʒast̪i.
9. ರಾಮು ನನಗೆ ಹಣ ಕೊಡಬೇಕು.
   ra:mu nanage hanna koḍabe:ku.
10. ದಿನಾ ಬೆಳಿಗ್ಗೆ ಕೋಳಿ ಕೂಗುತ್ತೆ.
   d̪ina beḷege koḷi ku:gut̪t̪e.

Set 3

1. ಆ ಪಕ್ಷಿ ಆಕಾಶದಲ್ಲಿ ಹಾರ್ತಾ ಇದೆ.
   a: pakʃi a:kaʃʌd̪alli harut̪t̪a id̪e.

2. ನೀನು ಈವತ್ತು ಪೂಜೆ ಮಾಡಬೇಕು.
   ni:nu ivat̪t̪u pu:dʒe maḍʌ beku.

3. ಅವಳು ಚೆನ್ನಾಗಿ ಹಾಡು ಹೇಳ್ತಾಳೆ.
   avaḷu tʃena:gi ha:ḍu heḷt̪a:le.

4. ಸಂಜೆ ಆರು ಘಂಟೆಗೆ ಕತ್ತಲಾಗುತ್ತೆ.
   sandʒe a:ru ganṭege kat̪t̪ala:gut̪t̪e.

5. ನಮ್ಮ ಮನೆ ಹತ್ತಿರ ಅಂಗಡಿ ಇದೆ.
   namma mane hat̪t̪ira angaḍi id̪e.

6. ಕಾಡಿಗೆ ಒಬ್ಬನೇ ಹೋಗಬಾರದು.
   ka:ḍige obbʌne hogʌ ba:rʌd̪u.

7. ಹಸು ಹಸಿ ಹುಲ್ಲು ತಿನ್ನುತ್ತೆ.
   hasu hasi hullu t̪inut̪t̪e.

8. ಸೀತೆ ಮನೇಲಿ ಗುಲಾಬಿ ಗಿಡ ಇದೆ.
   si:t̪e maneli gula:bi giḍa id̪e.

9. ನಿಮ್ಮ ಅಪ್ಪ ಮನೆಗೆ ಬರ್ತಾರೆ.
   nimma appa: manege bart̪a:re.

10. ಎಲ್ಲಾ ಕಾಗೆಗಳ ಬಣ್ಣ ಕಪ್ಪು.
    ella ka:gegala baṇṇa kappu.

APPENDIX 1(b)

list of paired words

Set 1		Set 2	
1.	ಬೇಳೆ-ಕಾಳು be:le - ka:ḷu	1.	ಈಗ - ಆಗ i:ga - a:ga
2.	ಹೊಲ- ಗದ್ದೆ hola - gad̪d̪e	2.	ಕಪ್ಪೆ - ಚಿಪ್ಪು kappe - tʃippu
3.	ಅತ್ತ - ಇತ್ತ at̪t̪a - it̪t̪a	3.	ಮನೆ - ಮಠ mane - matʰa
4.	ಸುತ್ತ - ಮುತ್ತ sut̪t̪a - mut̪t̪a	4.	ನಮ್ಮ - ನಿಮ್ಮ namma - nimma
5.	ಗಂಟು - ಮೂಟೆ ganṭu -mu:ṭe	5.	ಗುರು - ಶಿಷ್ಯ guru - ʃiʃja
6.	ತಾಯಿ - ತಂದೆ t̪a:ji -t̪ande	6.	ತಿಂಡಿ - ತೀರ್ಥ t̪indi - t̪irt̪ʰa
7.	ಅಂದ - ಚಂದ and̪a - tʃand̪a	7.	ಅಲ್ಲಿ - ಇಲ್ಲಿ alli - illi
8.	ಹೊಟ್ಟೆ- ಬಟ್ಟೆ hoṭṭe - baṭṭe	8.	ಸಣ್ಣ - ಪುಟ್ಟ saṇṇa - puṭṭa:
9.	ನಡೆ - ನುಡಿ naḍe - nuḍi	9.	ಕನಸು - ನನಸು kanasu - nanasu
10	ಕಷ್ಟ -ಸುಖ kaʃṭa - sukʰa	10.	ಗಂಟು - ಮೂಟೆ ganṭu - mu:ṭṭe

Set 3

1. ಮೀನ - ಮೇಷ
   mi:na - me:ʃa
2. ಬೆಟ್ಟ - ಗುಡ್ಡ
   beṭṭa - guḍḍa
3. ಅತ್ತ ಇತ್ತ
   at̪t̪a - it̪t̪a
4. ಹೆಚ್ಚು - ಕಮ್ಮಿ
   hetʃu - kammi
5. ಚಿನ್ನ ಬೆಳ್ಳಿ
   tʃinna - beḷḷi
6. ಕೆಲಸ - ಕಾರ್ಯ
   kelasa: - ka:rja
7. ಬಂಧು - ಬಳಗ
   band̪ʰu - baḷaga
8. ಗೆಜ್ಜೆ ಪೂಜೆ
   gedze - pudze
9. ದಾನ - ಧರ್ಮ
   da:na - d̪ʰarma
10. ಆಸ್ತಿ - ಪಾಸ್ತಿ
    a:st̪i - pa:st̪i