RECOGNITION OF ORIYA MONOSYLLABIC PB WORDS IN PRESENCE OF TEMPORALLY VARIANT NOISE

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A Dissertation Submitted in Part Fulfillment of
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ALL INDIA INSTITUTE OF SPEECH AND HEARING
MANASAGANGOTHRI
MYSORE-570006

Dedicated to

My Parents

Aneeta

&

My Dearest Friends

CERTIFICATE

This is to certify that this dissertation entitled ***'Recognition of Oriya Monosyllabic PB Words in Presence of Temporally Variant** Noise'* is the bonafide work submitted in part fulfillment for the degree of Master of Science (Audiology) of the student (Registration No. 06AUD004). This has been carried out under the guidance of a faculty of this institute and has not been submitted earlier to any other University for the award of any other Diploma or Degree.

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<u>CERTIFICATE</u>

This is to certify that the dissertation entitled ***'Recognition of Oriya Monosyllabic PB Words in Presence of Temporally Variant*** *Noise'* has been prepared under my supervision and guidance. It is also certified that this has not been submitted earlier in any other University for the award of any Diploma or Degree.

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DECLARATION

This is to certify that this dissertation entitled ***'Recognition of Oriya Monosyllabic PB Words in Presence of Temporally Variant Noise'*** is the result of my own study under the guidance of Dr. Asha Yathiraj, Professor and Head of the Department of Audiology, All India Institute of Speech and Hearing, Mysore, and has not been submitted in any other university for the award of any diploma or degree.

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INTRODUCTION

The ability of the ear to unravel the complexities of speech depends on many aspects of hearing. One of them is temporal resolution. Temporal resolution refers to the ability of a listener to resolve separate auditory events or detect changes in auditory stimuli over time (Moore, 1997). In conditions with competing background noise, the temporal resolution abilities of both normal hearing and individuals with a hearing impairment decreases. Assessing speech intelligibility in interrupted noise has been reported to reveal the auditory system's temporal ability to resolve speech fragments or get 'glimpses' or 'looks' of speech between the gaps of noise and to patch the information together to identify the specific speech stimuli (Miller, 1947).

The ability of people to follow or participate in a conversation decreases as the complexity of the auditory scene increases. When there is only one person talking in a quiet non-reverberant environment, people with good hearing find listening to be easy and effortless. However, as the auditory scene increases in complexity so does one's difficulty in following a conversation. Participating in a four-person conversation in a crowded, noisy, highly reverberant restaurant is quite difficult and tiring, even for young listeners with good hearing. For older listeners or for those with hearing impairment, communicating in such an environment is often been found to be virtually impossible.

Miller and Licklider (1950) reported the intelligibility of monosyllables as a function of the interruption rate of noise. For interruption rates below 200 Hz, the speech intelligibility increased as the rate was lowered. The maximum intelligibility was reached at about ten interruptions per second. For low rates, speech intelligibility dropped again because complete words were masked. It has been noted by Festen and Plomp (1986) that for an optimum modulation rate of noise about 16 Hz, the normal hearing listeners gained nearly 5.5 dB in signal-to-noise ratio relative to the threshold in steady-state noise. Fluctuating interference of speech are much more common in daily situations than steady-state noise (Festen & Plomp, 1990).

One obvious factor that contributes to a difficulty in communication in presence of noise is the signal-to-noise ratio (SNR). The SNR is often low, such that the energy in the competing sound sources masks the energy in the signal.

Temporal resolution of the ear can be measured in various ways: by the detection of a brief pause in a continuous sound (Plomp, 1964); by temporal masking (Fastle, 1979); by detection of modulation (Viemeister, 1979) and; by discrimination of signals having identical energy spectra (Green, 1985, cited in Festen and Plomp, 1990). Smiarowsky and Carhart (1975) suggested that forward masking and gap detection represent effects of the same underlying mechanism of auditory persistence. The most prominent modulation frequency between the speech and the masker is found to be 4 Hz, corresponding to half a period of 125 ms (Festen & Plomp, 1990). For normal listeners, the SRT for sentences in noise strongly depends upon the temporal distribution of the masker. For a noise masker varying in level like the envelope of speech, thresholds are found to be 4 to 6 dB lower than in steady-state noise (Festen & Plomp, 1990).

Need for the study

From the literature, it is evident that, speech perception of normal hearing individuals varies under fluctuating as well as steady-state noise. There is a need to know if the speech identification abilities of normal hearing individuals vary depending on whether the noise is interrupted temporally with different interruption rates. Further, noise in the environment occurs at different signal-to-noise ratios and often is fluctuating and not continuous. Hence, there is a need to know how individuals would perceive modulated noise in different signal-to-noise ratios. This would provide information about how individuals perform in a real life situation. Also, for those having problems in perception in the presence of noise the information from the study could be used to determine a hierarchy of activities that can be used while planning an auditory listening / training program in the presence of noise.

Aim of the study

The aims of the study were:

- To compare speech identification in different listening conditions (Continuous speech shaped noise, 16 Hz modulated speech noise & 32 Hz modulated speech noise) at different signal-to-noise ratios (0 dB & -5 dB).
- To compare speech identification in continuous Vs. temporally modulated speech noise
- To compare speech identification in the quiet condition with that of the masking conditions the presence of speech noise having a temporal modulation of 16 Hz with that of noise having a modulation of 32 Hz.

REVIEW OF LITERATURE

It has been proven time and again that the presence of background noise adversely affects the perception of speech. Kryter (1970) reported that when speech signal is masked, either partially or completely by a burst of noise, its intelligibility changes in a complex manner. Due to its harmful effects, noise has been termed as unwanted sound (Boyd, 1996; Dobie, 2001). Besides adversely affecting communication, noise has been found to damage hearing (Gloriag, Ward & Nixon, 1961; Kryter, 1973; Perez, Gatt & Cohen, 2000), cause other physiological changes (Carpenter, 1962, cited in Kryter, 1985) and affect the psychological well being of individuals (Burns, 1968, cited in Kryter, 1973). Noise interference with speech comprehension results in a large number of personal disabilities, handicaps and behavioural changes. Problems with concentration, fatigue, uncertainty and lack of self-confidence, irritation, misunderstandings, decreased working capacity, problems in human relations, and a number of stress reactions have all been identified (Lazarus, 1998). Smoorenburg (1992) reported that in everyday life, interfering noise is often speech noise.

Types of noise

In research studies, various types of noises have been utilized to determine their influence on the intelligibility of speech. These noises can be categorized based on their temporal pattern, based on their frequency characteristics as well as based on the source of noise.

Noise based on temporal parameters: The time varying aspects of noises that have been used in literature include: continuous noise, intermittent / interrupted noise and fluctuated / modulated noise (Hamernik & Hsueh, 1991; Ward, 1991). Studies have been done by Fleischer, Hoffman, Lang and Muller (1999) and Nelson, Jin, Carney and Nelson (2003) to determine the perception of speech in presence of continuous or un-modulated noise. The authors noted that continuous noise did not change but was continuous over time. Most of the machinery noises were included under this category of noise. It was also observed by them that continuous noise had a broader energy spectrum. Pollack (1955) described intermittent / interrupted noise as a noise which is produced by repeated bursts of noise with silent intervals or bursts with lesser amplitude between successive noise bursts. The same was also previously reported by Miller and Taylor (1948) and Miller and Licklider (1950). Modulated noise / fluctuating noise has been studied extensively by Miller (1947) and Miller and Licklider (1950). Nelson, Jin, Carney and Nelson (2003) noted that modulated noise could be either modulated in terms of amplitude or frequency. Unlike interrupted noise it was described not to have silence but contain dips which did have some amount of energy.

Noise based on frequency parameters: The types of noises have also been explained by Silman and Silverman (1991) as a function of frequency. Noises, varying in terms of frequency have been used in studies reported in literature over a long period of time. They include broad-band noise, narrow-band noise, complex noise and speech-shaped noise.

Broad-band noise, as described by Silman and Silverman (1991) was noise derived from a white noise signal. It was found to consist of an infinite number of frequencies and has equal power per cycle. The white noise which is shaped by the transducer was called as broad-band noise by them. On similar lines, narrow-band noise was also reported to be extracted from white noise. The only difference between narrow-band and broad-band noise was the selective bandwidth.

Complex noise was explained as a type of broad-band noise which has low frequency fundamental plus the multiples of fundamentals (Ahroon, Hamernik & Davis, 1993; Silman & Silverman, 1991). Silman and Silverman (1991) noted that usually the base frequency varied between 60 Hz to 120 Hz and the acoustic energy was present up to 4 kHz. Staab (1974, cited in Silman & Silverman, 1991) divided the complex noise into two basic types depending upon the energy spectrum pattern. He reported that a square wave noise could be achieved by generating a saw tooth and taking its harmonics, whereas by taking the multiples of the basic repetition rate instead of harmonics, a saw-tooth noise could be generated.

Martin (1975) reported that speech noise had the maximum masking effect for the speech signals. Speech noise was obtained by filtering the white noise above 1000 Hz at the rate of about 12 dB per octave (Silman & Silverman, 1991). They described speech noise as having more energy in the low frequency spectrum and resembling the spectrum of speech and hence it was a good masker for speech signals.

Noise based on source: Noise has being classified based on its source for social reasons. The types of noise generally being discussed are community noise and occupational noise. The World Health Organization (1999) defined community noise / environmental noise as noise emitted from all sources, except noise at the industrial workplace. It included road, rail, air traffic, construction and public work, and the neighbourhood. The noises that are emitted from industrial workplace have been included under occupational noise source (WHO, 2002).

Effect of background noise on communication

It has been reported by Kryter (1994) that most of the acoustic energy of speech is in the frequency range of 100 Hz to 6000 Hz, with the most important cue-bearing energy being between 300 Hz to 3000 Hz. The higher the level of noise, and the more energy it contains at the most important speech frequencies, the greater would be the percentage of speech sounds that become indiscernible to the listener. Environmental noise may also mask many other acoustical signals important for daily life, such as door bells, telephone signals, alarm clocks, fire alarms and other warning signals, and music (Kryter, 1994). The masking effect of noise on speech discrimination has been found to be more pronounced for hearing-impaired persons than for persons with normal hearing, particularly if the interfering noise is composed of speech or babble (Carhart, Tillman & Greetis, 1969).

Kryter (1994) also reported that for good speech intelligibility, the level of speech must be sufficiently high at any location. Human voice has been found to have limited power and speech level decreases with distance from the source. Korn (1954) advocated the need for an increase in vocal effort of 3.5 dB for each 10 dB increase in background noise level in a room. Whereas, Webster and Klumpp (1966) recommended a 7 dB increase in vocal effort for a 10 dB increase in noise level. Gardner (1963) examined the minimum conversational level required with an increase in background noise level in various settings. These values are provided in Table 2.1

Table 2.1: Conversational speech levels as a function of background noise

Environment	**Separation of participants**	**Talking level as measured at 1 meter (in**

		dB)
Face to face conversation		
Free space room	39 in 12 ft	49.5 53.5
Quiet office (NC-23)	39 in 12 ft	58.0 62.5
Face to face exchange of prepared text		
Free space room	39 in 12 ft	57.0 58.5
Quiet office (NC-23)	39 in 12 ft	64.0 66.5

French and Steinberg (1947) explained the reduction in speech reception in the presence of noise in terms of masking. Masking has been found to be most effective by a noise which has the same long term spectrum as speech noise (Miller & Nicely, 1955; Pickett, 1958). Speech perception for normal hearing listeners were noted to be affected more by steady-state noise than by fluctuating interfering signals such as competing speech (Carhart, Tillman & Greetis, 1969; Festen & Plomp, 1990).

Communication in terms of speech perception can also be affected by signal-to-noise ratio (SNR). The effect of SNR on speech perception will be discussed in the later part of the chapter.

Factors affecting masking of speech by noise

There are various factors which influence the masking of speech by noise. Some of the factors reported in the literature are: type of noise; amount of SNR present and; type of speech material used.

Effect of type of noise on speech perception:

Speech perception of any individual differs based on the type of noise which is used to mask the speech signal. The effect of various types of noises on speech perception has been mentioned in literature. Some of these noises include *white noise, speech noise, multi-talker babble, interrupted noise* and *modulated noise*. The below given review has mainly focused on interrupted and modulated noise.

White Noise: Keith and Talis (1972) compared the effect of white noise on PB scores in three different SNRs (+8, 0 and -8 dB). They found that the PB scores of normal hearing listeners deteriorated approximately by 52% from the quiet condition to the -8 dB SNR.

Filtered noise: Keith and Cohen (1976) used 500 Hz low-pass filtered noise and obtained the word recognition scores for normal hearing individuals and individuals with hearing impairment at two different SNRs (-4 dB and -12 dB). The material was presented at 40 dB SL and 96 dB SPL. They concluded that a more negative SNR resulted in poorer scores. Further, at the higher SPL, due to the spread of masking the scores were typically lower than that observed for individuals with hearing impairment. It has been reported that, persons with sensorineural hearing loss require 30 dB more intense speech compared with normals to achieve 40% discrimination (Tillman, Carhart & Olsen, 1970).

Competing sentences: Schneider, Li and Daneman (2007) reported that in the presence of competing sentences the normal hearing individuals performed poor.

They opined that competing sound source may initiate phonetic, semantic, and / or linguistic activity that interfered with the processing of the target speech.

It was observed in a study by Carhart, Tillman and Greetis (1969) that among the several maskers evaluated by them, that a continuous two-talker masker was more effective than continuous white noise in masking the recognition of spondee words. They also reported that a two-talker masker provided approximately 5 to 6 dB greater masking effect than white noise. This extra masking was termed as ‘perceptual masking’ by them.

Speech-shaped noise: Hall, Grose, Buss and Dev (2002) reported that speech shaped noise was more effective than an equally intense white noise in masking relatively redundant material such as spondees. They opined that this occurred because of the relatively greater masking in the lower frequencies provided by the speech-shaped noise masker. They observed a difference of 2.5 dB masking effect between these two types of maskers.

Wagener and Brand (2005) studied sentence intelligibility in the presence of noise in listeners with normal hearing and hearing impairment. They reported that stationary, speech-shaped noises produced identical results in the two groups. However, speech-simulating fluctuating noise yielded about 14 dB lower speech recognition thresholds (SRT) for the normal hearing individuals and about 10 dB lower SRTs for 20% of the individuals with hearing impairment. Of the individuals with hearing impairment, 30% did not benefit from the modulations and showed similar SRTs as for stationary noise. Using continuous noise yielded lower SRTs compared to gated noise. Glasberg and Moore (1989) and Plomp (1994) reported that when the background sound was a speech-shaped noise, the difference in threshold between the normal listeners and the hearing impaired were typically in the range of 2 to5 dB.

Interrupted noise: Using noise with an interruptions equivalent to 100% amplitude modulation by trains of rectangular pulses, Miller and Licklider (1950) evaluated speech identification. They used the monosyllabic PB words published by Egan (1948) and studied the effect of various rates of interruption on speech recognition. They utilized speech interrupted by silence, continuous speech masked by interrupted noise and a condition where speech and noise were alternated. They concluded from their study that when noise was introduced into the gaps between bursts of speech, when speech itself was interrupted by about 10 to 15 Hz, the speech was still intelligible but interruptions were evident. Whereas when the noise was introduced more intensely with higher interruption rates, the speech seemed to be continuous and un-interrupted.

Pollack (1955) reported that speech intelligibility decreased as the inter-burst level was increased for an interrupted masking noise of constant burst level. He found large improvements in speech intelligibility at lower repetition rates. Similarly, earlier Miller and Licklider (1950) observed that when the rate of interruption was 4 Hz or less, there was some loss of information because entire syllables and words were eliminated from the stimulus. However, once the interruption rate reaches 8 to 10 Hz, the words became as intelligible as un-interrupted speech.

In contrast, it has been found by Dirks and Bower (1970), Dirks, Wilson and Bower (1969) and Miller and Licklider (1950) that word intelligibility did not change significantly when continuous speech was intermittently masked by white noise and interruption rates were varied from 1 to 100 Hz. They carried out the study using a 0 dB SNR.

A few authors term the noise which has an interruption as ‘interrupted noise’ and a few term it as ‘modulated noise’. Miller and Licklider (1950) used a 100% amplitude modulated noise and termed it as interrupted noise. However, Smits and Houtgast (2007) used varying frequency modulations with a 50% amplitude modulation, and termed it as modulated noise. For ease some authors use the term fluctuating noise (Dirks & Bower, 1970).

Modulated noise: Festen and Plomp (1986) reported that while comparing continuous or steady-state noise with modulated noise, for optimum modulation rate of noise (16 Hz), the normal hearing listeners gained nearly 5.5 dB signal-to-noise ratio (SNR) relative to the threshold in steady-state noise, whereas the young hearing impaired listeners gained only 1.2 dB SNR. While comparing the interfering voice and steady-state noise, Festen and Plomp (1990) found that the correlation between intensity fluctuation and speech intelligibility dropped faster though apparent SNR was less sensitive to fluctuating masker.

A number of studies on speech recognition using *amplitude modulated masker* have been published. It has been reported by Carhart, Tillman and Johnson (1966) that when the masker was the speech from a single talker or noise modulated either periodically or the speech of a single talker, speech intelligibility improved compared to when un-modulated noise was used even if the modulated and un-modulated noise had equal average energy (Dirks, Wilson & Bower, 1969; Festen & Plomp, 1990). Multi-talker noise or noise modulated by multiple talkers were found to generally reduce speech intelligibility compared to unmodulated noise as reported by Danhauer and Leppler (1979). Whereas, Gustafsson and Arlinger (1994) found no difference for amplitude modulation of a masker to affect the speech intelligibility. They also reported that release of masking found at ±6 dB modulation was much smaller than at

±12 dB and 100%, whereas no significant difference was found between ±12 dB and 100% modulation, suggesting that after a certain modulation depth was reached, very little increase in masking effect could be seen. They inferred that at higher modulation rates the increased speech masking at higher modulation rates were seen which they explained in terms of temporal resolution. Temporal resolution referred to the ability of a listener to resolve separate auditory events or detect changes in auditory stimuli over time (Moore, 1996).

In conditions with competing background noise, the temporal resolution abilities for both normal hearing and hearing impaired has been found to decrease. Assessing speech intelligibility in interrupted noise has been reported to reveal the auditory system's temporal ability to resolve speech fragments or get 'glimpses' or 'looks' of speech between the gaps of noise and to patch the information together to identify the specific speech stimuli (Miller, 1947). The limited temporal resolution of the auditory system made the masker envelop variations less audible and less useful with regard to the collection of informative fragments of the speech signals as the modulation frequency was increased (Gustafsson & Arlinger, 1994).

Experiments on signal detection in *temporally modulated broad-band noise* have revealed that the detection cue is not solely based on the information in the critical band centered at the signal but that information (about temporal modulation) in off-signal co-modulation frequency bands also play a role. The phenomenon of co-modulation masking release was initially explained by Hall, Haggard, Fernandes (1984). They found a release of masking for the detection of a tone pulse in a narrow band of noise, if a second narrow band noise was added, remote in frequency. Release from masking occurred in different ways. In two-tone suppression, when a second tone was added to a tonal masker at a frequency 10 to 20% higher, it improved the audibility of the masked tone. In signal enhancement (temporal decline of masking) a simultaneous masked signal has been observed to be easier to hear (about 10-15 dB) when its onset was delayed relative to that of the masker (Dang & Honda, 1997).

Fant (1960, cited in Silman & Silverman, 1991) explained a related phenomenon which dealt with the release from broad-band masking of speech by modulating the noise. Sinusoidal modulation at 10 to 20 Hz allowed significant low-noise intervals of about the duration of the phoneme, thus raised the intelligibility. This was reasoned as at lower rates many phonemes were entirely masked and at higher rates the reduced noise window was too short to help perception.

Results from the study of Smits and Houtgast (2007) revealed that, individuals with normal hearing benefited from interruptions in noise while listening to digits in noise. The masking release was reported to be higher for the 16 Hz interruption than for 32 Hz interruption. The highest digit identification scores were obtained for 16 Hz modulated noise and lowest were for continuous noise.

Several studies have demonstrated that in fluctuating (modulated or interrupted) noise, normal hearing individuals performed better than hearing impaired individuals (Bacon, Opie & Montoya, 1998; Eisenberg, Dirks & Bell, 1995; Festen & Plomp, 1990; Hagerman, 2002; Wagener & Brand, 2005). Hearing impaired individuals benefited less from short periods of relatively low noise levels that occurred in modulated or interrupted noise. Even the hearing impaired individuals showed improvement in speech identification scores while going from continuous noise to modulated noise. For normal individuals the masking release was found to be of a range of a few dB to more than 15 dB depending on the modulation of the noise characteristics. It has been reported that masking release is higher for interrupted noise than for modulated noise (Bacon, Opie & Montoya, 1998), masking release increases with modulation depth (Gustafsson & Arlinger, 1994; Howard-Jones & Rosen, 1993) and the greatest masking release occurred at rates between 10 Hz and 20 Hz (Gustafsson & Arlinger, 1994; Miller & Licklider, 1950).

Signal-to-noise ratio (SNR):

Speech masking ability of a noise has also been noted to dependent upon the relation between the intensity of the speech and noise (Fant, 1960, cited in Silman & Silverman, 1991). This has been termed as signal-to-noise ratio. He reported speech perception as a process that consisted of both successive and concurrent identification on a series of progressively more abstract levels of linguistic structure. For satisfactory communication, the signal-to-noise ratio was estimated to be +6 dB. When the criterion was not met, speech perception dropped drastically. Moore (1996) noted that at a 0 dB signal-to-noise ratio word articulation scores reached 50%.

Hawkins and Stevens (1950) while increasing the level of noise found that, the speech recognition threshold (SRT) quickly reached asymptotic behaviour in which a certain increase of noise level was followed by an equal increase in speech recognition threshold. They concluded saying that SRT can be expressed in terms of SNR. They found the threshold intelligibility of connected discourse to be -8 dB SNR whereas the threshold for detection of speech signal was -17 dB. Kryter (1962) reported that, an increase in 1 dB in SRT implies a decrease in discrimination score of about 6%.

Olsen, Olofsson and Hagerman (2005) studied the effect of audibility, signal-to-noise ratio and temporal speech cues in presence of modulated noise. They modulated the noise though either fast acting compression or linear amplification. The sentences were presented at four SNR levels (-15, -10, -5 and 0 dB). They found that the scores obtained from the fast acting compression modulated noise were better than that of the linear amplification. This was justified by them saying that the scores with fast acting compression modulated noise were better due to high release of temporal masking. They again concluded that the level of SNR affected the speech intelligibility scores adversely in both the modulation conditions.

Groen (1969) evaluated the phoneme scores for individuals with hearing impaired and normal hearing individuals in presence of three SNRs (-5, 0 and +5 dB SNR). He observed that at -5 dB SNR the scores reduced drastically whereas at +10 dB the scores were significantly higher compared to at 0 dB SNR for hearing impaired individuals. For normal hearing group he found significantly lower scores at -5 dB SNR whereas no significant difference in scores were found for 0 dB and +10 dB. On the similar lines Kamlesh (1998) studied the effect of three SNR conditions (-5, 0 and +5 dB) on hearing impaired individuals using paired word (Kannada) recognition and questions. She reported that at adverse SNR the scores were significantly lower and with increase in SNR the scores improved. In the present study the similar results were obtained with the lowest scores for -5 dB SNR and better scores for 0 dB SNR in all the masking noise conditions. It is well documented in literatures about the need of speech perception tests in presence of noise for hearing aid selection (Carhart, 1965; Tillman, Carhart & Olsen, 1970; Miller, Heise & Lichten, 1951; Stuart & Phillips, 1996).

An investigation of the speech understanding in quiet and noise conditions was carried out by Hallgren, Larsby, Lixell and Arlinger (2005). This was studied with and without hearing aids for 12 hearing impaired individuals. On investigation they found that hearing aid improved the speech recognition by 7 dB in quiet but did not improve significantly at an SNR of 2.5 dB.

It was found that monosyllabic word scores dropped significantly when speech at a constant SNR was increased from 80 to 130 dB SPL (Kryter, 1946, Pickett & Pollack, 1958). Studebaker, Sherbecoe, McDaniel and Gwaltney (1999) reported that even modestly high speech levels (> 69 dB SPL) produced substantial reduction in speech recognition performance under conditions in which the SNR remained constant. They observed the biggest effect at SNR that produced scores near 50 rau but performance reduced once the SNR exceeded 15 to 18 dB. Duquesnoy and Plomp (1980) and Hawkins and Stevens (1950) found that the SNR needed to achieve a fixed performance level remained constant as a function of masker intensity. Studebaker, Sherbecoe, McDaniel and Gwaltney (1999) stated that "The effect of speech and noise level are synergetic. The negative effects of added noise level are greater when the speech level is high" (p:2443).

It is well known that younger children have greater difficulty understanding speech in even modest levels of ambient noise (Elliott, 1979; Newman & Hochberg, 1983; Nittrouer & Boothroyd, 1990). Several authors have reported results showing that the ability to recognize speech in noise improves systematically with age (Elliott, 1979; Finitzo-Hieber & Tillman, 1978; Marshall, 1987).   It is clear that children need quieter conditions and corresponding larger signal-to-noise ratios than adults to achieve high speech recognition scores (Elliott, 1979).

Elliott (1979) investigated the speech intelligibility in noise for children aged 9 years to 17 years in the presence of three SNR levels (-5 dB, 0 dB and +5 dB). He found at 0 dB SNR performance of 11 year old children and 13 year old children were significantly poorer compared to 15 and 17 year old children. Highest scores were obtained for children aged 17 years and lowest were for 9 year olds. At -5 dB SNR scored were reduced for all age groups.

Hall, Grose, Buss and Dev (2002) reported that children showed approximately 4 dB more perceptual masking than adults in continuous masker. This suggested that children may have more difficulties than adults in the natural environments when attempting to understand desired speech signals in the presence of competing background noise.

It was noted by Nabelek and Pickett (1974) that the overall effects of noise on speech perception could be inferred from a speech-in-noise ratio (SNR) expressed in dB. Speech recognition scores were generally higher with higher SNR and low when the SNR was low. Pearson, Bennett and Fidell (1977) reported that the average A-weighted background noise levels at schools and homes to be between 45 dB and 55 dB. The average speech level was found to be approximately 65 dB measured at 1 meter distance from the mouth of the talker which provided an SNR of +10 dB and +20 dB. For speech perception with ease a SNR of +15 dB has to be maintained. Hence, in their report, they concluded that the SNR at schools are less than the required criteria and affects the speech perception of children.

Smits and Houtgast (2007) reported that background noise reduced the intelligibility of speech by masking or distorting the acoustic cues in the speech signal. He demonstrated that 42 dBA external traffic noise reduced the intelligibility of monosyllabic words in the classroom to below 50% correct when the SNR reached -15 dBA. Again in 2001, doing the research in the similar lines Lukas et al. found similar results.

Performance of children in school has been found to be affected by noise. Cohen, Evans, Krantz, Kelly and Kelly (1981) reported further detrimental effects of noise on students in classrooms. Likewise, Lukas, Dupree and Swing (1981) in a study of the effects of road traffic noise, found reduced performance on reading and math tests. The reading test scores of the sixth grade students exposed to noise were 0.7 years behind comparable students in quieter school. Finitzo-Hieber and Tillman (1978) reported that a classroom with SNR not less than +6 dB (preferably +12 dB) were favourable for normal children. Sanders (1965) found the SNR to be of +1 to +5 dB in kindergarten and elementary schools respectively. Whereas Gengel (1971) strongly recommended that for hearing impaired children to get optimum benefit the SNR should be maintained at +15 dB to +20 dB. In the similar lines Finitzo-Hieber and Tillman (1978) suggested a SNR of +12 dB in classrooms.

Rankovic and Levy (1997) reported that broad-band speech at an SNR +15 dB yielded a lower mean performance that speech in quiet which was high pass filtered at 1 or 1.5 kHz or low pass filtered at 3 kHz. Studebaker, Sherbecoe, McDaniel and Gwaltney (1999) showed that beyond 15 dB SNR the intelligibility of speech decreased, contradicting the predictions provided by ANSI (2002).

Bradley, Reich and Norcross (1999) estimated the maximum acceptable ambient noise levels that provided near ideal speech communication for students of various ages. They concluded that 6 year old students required an SNR of 7 dB higher than those of 11 year old students.

In literature, studies have been carried out to evaluate the performance of individuals having a hearing loss in different SNRs. A few of them are discussed below. Elpern (1960) and Ross, Huntington, Newby and Dixon (1965) found a large difference in the mean speech discrimination scores for the normal hearing and hearing impaired group when used two CID W-22 word list at +12 dB SNR.

Barrenas and Wikstrom (2000) investigated the speech recognition scores in noise in audiological patients and general population. They presented monosyllabic words in quiet and in the presence of +4 dB SNR. They reported that with normal hearing, age did not influence the results. Young persons with hearing loss obtained higher scores at a fixed SNR condition than older persons with the same degree of hearing loss.

Age related differences in identification and the recall of sentence final words heard in a babble background were investigated by Schneider, Li and Daneman (2007). They varied the level of babble to determine the psychometric function (correct identification as a function of SNR) for presbycusis, old-adults with normal hearing and young-adults with normal hearing. The word identification scores reduced with increase in SNR which was seen more evidently with the individuals with presbycusis and old-adult normal hearing individuals. They reported that the scores for young-adults too did deteriorated though the difference was not to the extent of the other two groups. The young adults could obtain a score of 40% at -5 dB SNR whereas old-adults required a SNR of 0 to +5 dB and individuals with presbycusis required a SNR of more than +10 dB. Plomp and Mimpen (1979) suggested for better speech intelligibility, the SNR to be more than +5 to +10 dB for elderly individuals.

From these studies it can be observed that the SNR is an important component for effective communication to take place. The recommended SNR has varied across studies. Most studies note that in children and senior citizens, higher SNRs are required.

Type of speech material used:

The type of speech material being used has also been noted to affect speech perception in the presence of noise. The effect of the speech material is briefly discussed below.

Various studies reported that speech intelligibility varied depending upon the type of test material used: phonemes, words (digits, alphabet, meaningful words, non-sense CVC word), sentences, free conversation. Egan (1948), Miller et al. (1951) and Hirsh, Reynolds, and Joseph (1954) reported that the number of sounds in a word as well as the number of syllables had affected the speech intelligibility. Miller et al. (1951) reported that the performance intensity (PI) function plotted for single-syllable words became steeper when the same words were heard in sentences.

Martin (1975) reported that non-sense syllables gave a quick and easy assessment of speech intelligibility and could be used across various linguistic groups without influencing the intelligibility. Whereas Lehiste and Peterson (1959) explained non-sense syllables as the isolated phonemes and it did not carry any meaning and did not possess the property of intelligibility. Carhart (1965) supported Peterson saying the non-sense syllables to be abstract and created confusion to the individuals. According to him, monosyllables have reduced redundancy as they were sufficiently unpredictable. In addition, they served as an easy task for the listener because of contextual cues (Miller, Heise & Litchten, 1951).

Lehiste and Peterson (1959) and Pisoni, Nusbaum and Green (1985) reported that sentences gave more redundant cues as compared to words or syllables. Hence, better speech intelligibility was obtained. Hagerman (1982, 1984) investigated a Swedish sentence test in noise (noise, synthesized from speech material to have the same long term spectrum as speech: speech presented at 65 dB SPL with ± 3 dB SNR) and obtained a very steep intelligibility curve (25 per cent per dB at the maximum) for the normal hearing subjects. However, monosyllabic word lists generally gave greater threshold shifts in noise than sentence lists in subjects with a hearing loss. It was reasoned by Jayaram, Baguley and Moffat (1992) that because the former does not provide linguistic cues to the same extent as the latter. It was deduced from this that the performance scores on monosyllabic words were more sensitive indicators of discrimination in noise than scores on sentences. Tests using sentence lists also imposed a demand on the linguistic ability of the patients thus yielded confounded results. For these reasons a monosyllabic word test in noise was thought to be a more appropriate choice in assessing the difficulty the hearing impaired may experience in noise (Jayaram, Baguley & Moffat, 1992).

The above review of literature brings to light that a variety of noise types have been utilized to study their effect on communication. Modulated noise is one such type of noise that has been found to affect speech perception. Variations in perception have been noted depending on the rate of modulation of the noise. Studies differ regarding the exact rate of modulation that brings about optimum speech perception.

There is a general consensus that as the SNR is reduced the perception of speech also reduces. While several studies have evaluated the effects of SNR, relatively few studies have studied the combined effect of modulation rate and SNR. There is a need to study such an effect since in real life, combinations of variables co-exist.

METHOD

Participant Selection

To evaluate the effects of continuous versus interrupted noise on the speech perception, the present study was undertaken. This effect was studied on Oriya language. Thirty individuals in the age range of 20 years to 50 years were evaluated in the study. All the individuals knew the dialect of Oriya spoken in Bhubaneswar region of Orissa.

The participants did not have a history of any ear disorders. As they needed to provide an oral response, it was ensured that they even did not have any speech or language disorders. In addition, in order to be included into the study, the participants had to have pure-tone thresholds within 20 dB HL. The participants whose speech identification scores were above 80% using the Oriya monosyllable PB wordlist, developed by Behera and Yathiraj (2004) were selected. All of the participants had A' type tympanogram with reflexes present in both the ear and passed the Screening Checklist for Auditory Processing (SCAP) developed by Yathiraj and Mascarehans (2002).

Instrumentation

A calibrated double channel, diagnostic audiometer, Orbiter 922 with TDH-39 headphone was used for the pure tone air conduction testing and speech audiometry. A Radio Ear B-71 vibrator was used for estimating bone conduction thresholds. A calibrated middle ear analyzer, (GSI- Tympstar) provided tympanometry and reflexometry information.

The speech and noise stimuli were presented through a Pentium 4 computer. The signals from the computer were routed to the audiometer.

Material Development

The material development involved the recording of an existing Oriya speech identification test and the generation of noise to be used for masking. Both were done using a Pentium IV computer with Adobe Audition 2.0 software.

Monosyllabic Phonemically Balanced (PB) Words of Oriya language, developed by Behera and Yathiraj (2004) was used. The test contains four half lists having phonemically balanced words. Each half list had 25 monosyllabic words. The words were recorded digitally by a female Oriya speaker, who was fluent in the dialect of Oriya spoken in Bhubaneswar region of Orissa. The recordings were done using a Philips unidirectional microphone, connected to a Pentium IV computer. The recorded data were digitized using the Adobe Audition 2.0 software. The recorded materials were scaled so that all the words were equally loud. Further, the four lists were randomized using a randomization table to form eight lists. Prior to each list a 1 kHz calibration tone was recorded. The materials were administered on 10 normal hearing Oriya speakers to ensure that the material was clearly recorded.

Speech shaped noise was generated with Adobe Audition 2.0 software based on the parameters of given by Silman and Silverman (1991). As suggested by them a broadband noise was filtered to have a frequency range of 250 hz to 4000 Hz. The slope of the speech spectrum was +3 dB per octave from 250 Hz to 1 kHz and 12 dB per octave from 1 kHz to 4 kHz.

The speech shaped noise was further modulated to get 16 Hz and 32 Hz modulated noise. This was done using the MATLAB 7.0 software. The noises were then mixed with the recorded speech materials using the Adobe Audition 2.0 software. The following six conditions were thus generated:

- Continuous speech noise + speech at 0 dB SNR
- 16 Hz modulated noise + speech at 0 dB SNR
- 32 Hz modulated noise + speech at 0 dB SNR
- Continuous speech noise + speech at -5 dB SNR
- 16 Hz modulated noise + speech at -5 dB SNR
- 32 Hz modulated noise + speech at -5 dB SNR

An example of a waveform for the word /kar/is provided in Figure 3.1. Also given in Figure 3.1 are the waveforms for continuous noise, 16 Hz modulated noise, 32 Hz modulated noise. The combination of the test stimulus /kar/ with all the different types of noises used at 0 and -5 dB SNR are given in Figure 3.2.

Fig. 3.1: Waveforms of the word /kar/, continuous noise, 16 Hz modulated noise and 32 Hz modulated noise

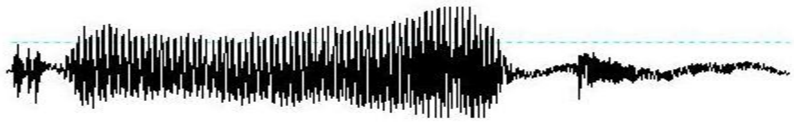
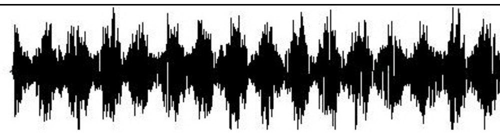
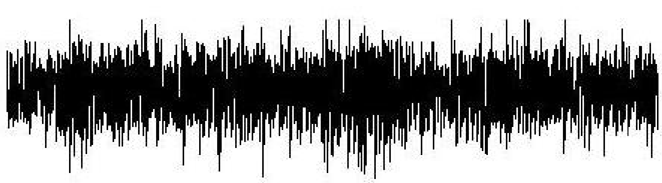
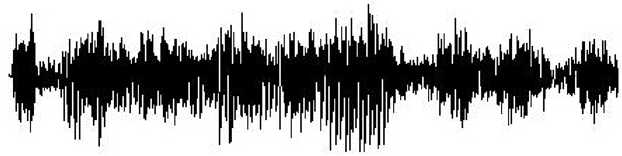
/kar/	
Continuous noise	
16 Hz modulated noise	
32 Hz modulated noise	

Figure 3.2: Waveforms of the word /kar/ in combination with continuous noise, 16 Hz modulated noise and 32 Hz modulated noise at 0 dB and -5 dB SNR

/kar/ with continuous noise at 0 dB SNR	
/kar/ with continuous noise at -5 dB SNR	

/kar/ with 16 Hz modulated noise at 0 dB SNR	
/kar/ with 16 Hz modulated noise at -5 dB SNR	
/kar/ with 32 Hz modulated noise at 0 dB SNR	
/kar/ with 32 Hz modulated noise at -5 dB SNR	

Environment:

All the tests were carried out in a sound treated suite. The noise levels were within permissible levels specified by ANSI 1991 (S 3.1-1991, cited in Wilber, 1994).

Procedure:

The recorded speech materials were played on a Pentium-4 computer with the help of the Adobe Audition 2.0 software and routed through audiometer and presented through headphones. All participants heard the speech signals at an intensity of 40 dB HL. In the two SNR conditions, the level of the signal was held constant, while the level of the noise varied. Thus, in the -5 dB SNR condition the speech materials were presented at 40 dB HL and the noise was presented at 45 dB HL. The speech as well as noise was heard in the same ear. The choice of ear was randomized such that half the participants heard the signal through right ear and the other half through the left ear. The order in which each of the participants heard these lists were randomized to avoid any list effect. No participant heard the same list more than once.

The participants were instructed to repeat the words heard by them. The oral responses of the participants were scored. Every correct response was given a value of one and an incorrect response a score of zero.

Analyses:

The data thus obtained were subjected to statistical analysis. Details regarding this are further discussed.

RESULTS & DISCUSSION

The aim of the present study was to see the effect of temporally modulated noise on speech perception using Oriya monosyllable phonemically balanced (PB) words. The speech identification abilities were determined in a quiet condition and in the presence of three masking conditions (continuous noise, 16 Hz and 32 Hz modulated noises) at two signal-to-noise ratios (0 dB and -5 dB). The data from thirty normal hearing participants were analyzed using the Statistical Package for Social Sciences (SPSS) software version 15. The following statistical analyses were done:

- Descriptive analysis for all the conditions,
- Two-way repeated measures of ANOVA to find out the main effect,
- Bonferroni pairwise comparison when the ANOVA results showed a significant difference,
- Paired sample 't' test to find out the significant difference between the different listening conditions and,
- One-way repeated measures of ANOVA to compare conditions within each signal-to-noise ratio (SNR).

The rationalized arcsine transform, developed by Studebaker (1985) was done to convert the speech identification scores into rationalized arcsine units (rau). This was done since it has been observed by Studebaker (1985) that speech identification scores are non-linear or additive. This was found to result in the critical difference between two speech identification scores being unequal. Hence, the available scores were converted to rau scores using the RATARC online rationalized arcsine transform program developed by Studebaker (1985). Thus, all statistical analyses were done for the word scores as well as for the rau scores.

The above analyses were done to obtain information regarding the following:

- Effect of different listening conditions (quiet, two SNR conditions and three masking conditions)
- Effect of signal-to-noise ratio (0 dB and -5 dB SNR)
- Comparison of quiet and masking conditions (continuous noise, 16 Hz and 32 Hz modulated noises at the two SNRs).

Effect of different listening conditions

The mean and the standard deviation of the speech identification scores in quiet and in the presence of noises were calculated separately. The mean speech identification scores were better for the quiet condition compared to the masking conditions. Among the difference noise conditions, better mean speech identification scores were obtained in the presence of 16 Hz modulated speech shaped noise at 0 dB SNR. In contrast, poorer scores were obtained for the 32 Hz modulated speech shaped noise at -5 dB SNR condition. The mean and the standard deviation of the raw scores for the different conditions are given in Table 4.1 and Figure 4.1.

Also provided are the mean and standard deviation (SD) of the rau scores in Table 4.1 and Figure 4.2. Similar results were obtained for rau scores in all the listening condition as mentioned above. Among the difference noise conditions, better mean speech identification scores were obtained in the presence of 16 Hz modulated speech shaped noise at 0 dB SNR. In contrast, poorer scores were obtained for the 32 Hz modulated speech shaped noise at -5 dB SNR condition.

Table 4.1: Mean and Standard deviation (SD) for the speech identification (raw and rau) scores in different listening conditions

Listening Conditions	SNR	Raw scores		rau scores	
		Mean#	**Standard deviation (SD)**	**Mean**	**Standard deviation (SD)**
Quiet	-	23.90	1.09	102.51	9.74
Continuous noise	0 dB	19.93	2.66	79.37	11.86
Continuous noise	-5 dB	18.33	1.54	71.86	6.24
16 Hz modulated speech noise	0 dB	20.67	1.24	81.90	5.80
16 Hz modulated speech noise	-5 dB	19.53	1.11	76.74	4.63
32 Hz modulated speech noise	0 dB	19.03	1.79	74.92	7.91
32 Hz modulated speech noise	-5 dB	18.23	1.70	71.42	7.33

Maximum score = 25

In order to check whether there was a significant difference between the different noise conditions and also the different SNR conditions, two-way repeated measure ANOVA was done (3 noise conditions × 2 SNRs). The ANOVA results showed a significant main effect for different noise conditions [$F (2, 58) = 8.52$, $p < 0.01$] and different SNR conditions [$F (1, 29) = 52.35$, $p < 0.01$]. It also showed a significant interaction effect between the different noise and SNR conditions [$F (2, 58) = 3.68$, $p < 0.05$].

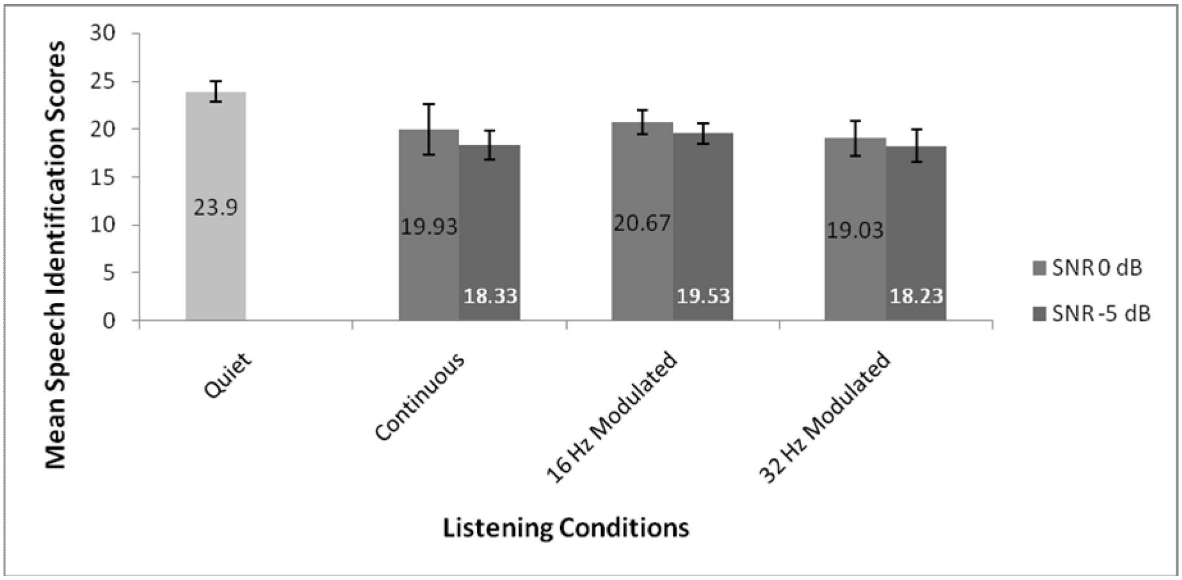


Figure 4.1: Mean and standard deviation for the raw speech identification scores across different listening situations and two different SNRs

ANOVA results for rau scores too showed a significant main effect for different noise conditions [F (2, 58) = 7.90, p < 0.01] and different SNR conditions [F (1, 29) = 53.45, p < 0.01]. It also showed a significant interaction effect between the different noise and SNR conditions [F (2, 58) = 4.39, p < 0.05].

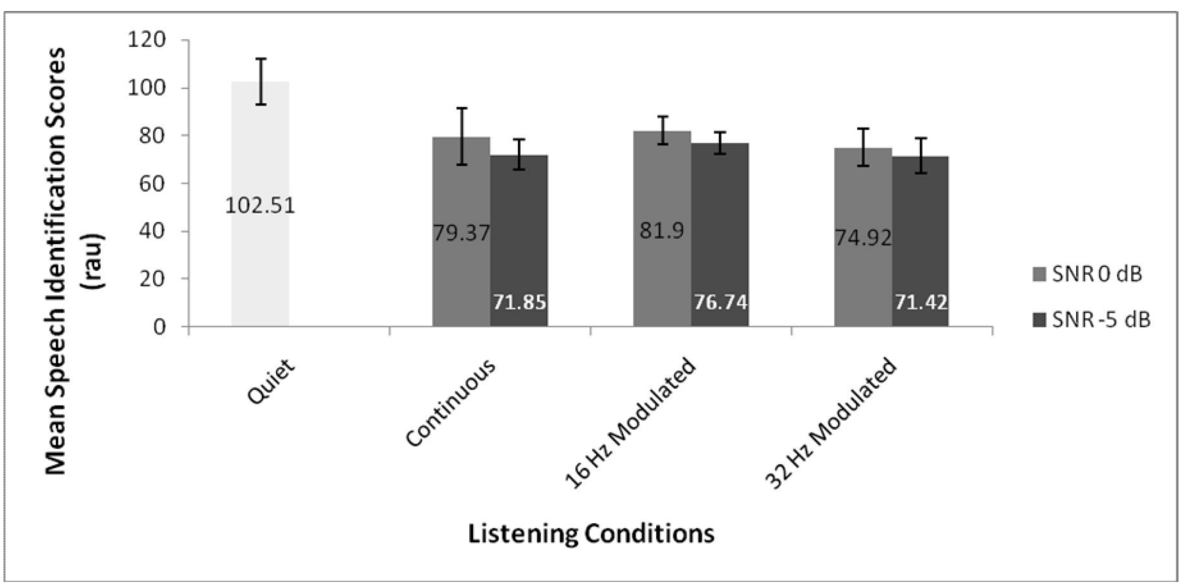


Figure 4.2: Mean and standard deviation for the rau speech identification scores across different listening situations and two different SNRs

Since the two SNR conditions were significantly different, separate one-way ANOVAs were done. This was done to see the significance of difference for different masking noise conditions at each of the two SNRs. A significant main effect was seen for the 0 dB SNR [$F(2, 58) = 6.99$, $p < 0.01$] and -5 dB SNR [$F(2, 58) = 9.24$, $p < 0.01$].

Table 4.2: Pairwise comparison of different listening conditions at 0 dB SNR for raw scores

0 dB SNR		
Masking noise condition	16 Hz modulated	32 Hz modulated
Continuous	$p > 0.05$	$p > 0.05$
16 Hz modulated	-	$p < 0.05$

Table 4.3: Pairwise comparison of different listening conditions at -5 dB SNR for raw scores

-5 dB SNR		
Masking noise condition	16 Hz modulated	32 Hz modulated
Continuous	$p < 0.05$	$p > 0.05$
16 Hz modulated	-	$p < 0.05$

Similarly, on analysis of the rau scores a significant main effect was seen. This was observed for the 0 dB SNR [$F(2, 58) = 6.60$, $p < 0.01$] and -5 dB SNR [$F(2, 58) = 8.75$, $p < 0.01$] conditions.

Further, Bonferroni pairwise comparison was done to check the significance of difference between the different masked noise conditions. At the 0 dB SNR, a significant difference between the 16 Hz modulated speech noise condition and 32 Hz modulated noise condition were observed. However, unlike the expected findings, there was no significant difference between the continuous and the modulated speech noise conditions (Table 4.2). On the other hand, the pairwise comparison for the -5 dB SNR revealed a significant difference ($p < 0.01$) between all the three masking noise conditions ($p < 0.01$). However, like that obtained at 0 dB SNR condition, no significant difference ($p > 0.05$) was seen for the continuous and the 32 Hz modulated noises.

Similar results were found for the rau scores at both SNRs. Probably, identical results were obtained for the raw and rau scores since the values obtained in the present study did not contain scores along the entire range of scores. Most of the speech identification scores across all conditions were concentrated only in the upper extreme of the range.

It has been reported by Miller and Licklider (1950) and Gustafsson and Arlinger (1994) that at higher modulation rates, the release from masking was less. Hence, the speech intelligibility at higher modulation rates such as 32 Hz tended to be similar to be that observed for continuous or steady-state noise. In contrast, they reported that for maskers with lower modulation rates of 10 Hz (Miller & Licklider, 1950; Gustafsson & Arlinger, 1994) and 16 Hz (Smits & Houtgast, 2007), the release of masking was more, resulting in better speech perception compared to continuous noise makers. Similar results were also found by Smits and Houtgast (2007).

In the present study, such a release from masking was observed only at the -5 dB SNR and not at 0 dB SNR. This indicates that only at a more adverse SNR condition, did the release of masking occur. Unlike the expected finding, no release in masking was obtained at the 0 dB SNR condition, even when the participants with extreme scores were eliminated. Hence, subject variability cannot account for the lack of release of masking at 0 dB SNR.

In the present study, the scores obtained using continuous masking noise were lower than that obtained with the 16 Hz modulated noise at -5 dB SNR. However, at the same SNR, no improvement was seen for the 32 Hz modulation rate compared to the continuous noise. This is in agreement with the results of various previous studies, where the masking release was reported to be higher for modulated noise than for continuous noise (Miller & Licklider, 1950; Gustafsson & Arlinger, 1994). It has also been reported by Smits and Houtgast (2007) that at higher modulation rates of 32 Hz, the noise functions similar to continuous noise and the advantage from release of masking does not occur.

Effect of signal-to-noise ratio (SNR)

Further, from the mean values given in Table 4.1, it can be observed that the speech identification scores were higher for the 0 dB SNR condition and lower for the -5 dB SNR condition. This was observed for continuous masking noise and both modulation masking (16 Hz and 32 Hz) conditions.

Paired sample 't' test was done to see if these differences in mean scores across the two SNRs were significantly different. The paired sample 't' test revealed a significant difference between the speech identification scores at the two different SNRs. This significant difference between 0 dB and -5 dB SNR ($p < 0.01$) was present in all the three masking conditions (continuous noise, 16 Hz modulated noise & 32 Hz modulated noise). This is evident from the information given in Table 4.4. Similar results were seen for the rau scores too.

Table 4.4: Significance of difference of different masking conditions at the two SNRs

Listening Conditions	SNR	Mean#	Standard deviation (SD)	't' value
Continuous noise	0 dB	19.93	2.66	4.94**
	-5 dB	18.33	1.54	
16 Hz modulated speech noise	0 dB	20.67	1.24	5.78**
	-5 dB	19.53	1.11	
32 Hz modulated speech noise	0 dB	19.03	1.79	5.17**
	-5 dB	18.23	1.70	

** Significant at $p < 0.01$ # Maximum score = 25

The finding of the present study is in consonance with that of Groen (1969) and Kamlesh (1998). They too reported that at higher SNR the speech identification scores were higher and was at lower SNR of -5 dB scores dropped. This drop in scores has been attributed to the masking that occurs at lower SNRs. Similar findings have also been noted by Olsen, Olofsson and Hagerman (2005) while using different other signal-to-noise ratio.

Effect of quiet Vs. masking conditions

The mean and standard values given in Table 4.1 clearly reveal that the speech identification scores were comparatively higher for the quiet condition than for any masking condition (continuous or modulated). Amongst the masking conditions, highest scores were obtained for 16 Hz modulated noise at 0 dB SNR and the lowest scores were obtained for 32 Hz modulated noise at -5 dB SNR condition.

To check for a significant difference between the quiet and the different masking conditions, paired 't' test was done. A significant difference between the quiet and all the different masking conditions was obtained. From Table 4.5 it can be noted that, the scores obtained in the quiet condition were significantly higher than that obtained with any of the masking conditions. Thus, irrespective of whether the masking noise had a modulation rate of 16 Hz / 32 Hz or had a SNR of 0 dB / -5 dB, it resulted in significantly lower scores than the quiet condition. Similar results were obtained with the rau scores as well.

Table 4.5: significance of difference between the quiet and different noise conditions

Listening Conditions	Mean#	't' value
Quiet	23.90	7.67 ***
Continuous noise at 0 dB SNR	19.93	
Quiet	23.90	15.42 ***
Continuous noise at -5 dB SNR	18.33	
Quiet	23.90	15.60 ***
16 Hz modulated noise at 0 dB SNR	20.67	
Quiet	23.90	18.79 ***
16 Hz modulated noise at -5 dB SNR	19.53	
Quiet	23.90	13.13 ***
32 Hz modulated noise at 0 dB SNR	19.03	
Quiet	23.90	15.09 ***
32 Hz modulated noise at -5 dB SNR	18.23	

*** Significant at $p < 0.001$ # Maximum score = 25

From the findings of the present study it can be noted that in the presence of masking noise, speech identification scores in normal hearing adults drops drastically. Even the least of the masking conditions (16 Hz at 0 dB SNR) was highly significantly different from the perception obtained in the quiet situation. The findings of the current study with regard to the comparison between the quiet and masking conditions are in agreement with that reported by Miller and Nicely (1955).

Though the present study was carried out with adult normal hearing participants, it can be construed that similar noise conditions would have a much more adverse affect on children. Studies in literature, comparing the performance of children with adults on speech intelligibility in noise, have shown that the former group performs poorer than the latter group (Elliott et al., 1979; Newman & Hochberg, 1983; Nittrouer & Boothroyd, 1990). Further, noise levels in classrooms have been found to range from +35 dB to -10 dB as reported by Nebelek and Pickett (1974). It is possible that the intermittent noise present in the classrooms would have a highly negative effect on speech perception and hence the learning abilities of children. Thus, it is essential that noise levels should be much lower than what has been utilized in the present study in order to enable children to perceive speech effectively.

From the findings of the present study, it can also be extrapolated that if individuals with normal hearing are adversely affected with masking noise, those with a hearing loss are likely to be more adversely affected. In addition, Barrenas and Wikstrom (2000), Elpern (1960), Schneider and Daneman (2007), and Ross and Huntington (1962) have reported that those with hearing impairment are likely to have more difficulty in speech perception in the presence of noise.

From the findings of the study the following can be observed:

- There was no significant difference between the speech identification scores got in the continuous noise masking condition and the two modulated masking conditions at the 0 dB SNR condition.
- There was a significant difference between the speech identification scores got in the continuous noise masking condition and the 16 Hz modulated masking conditions at the -5 dB SNR condition. However, no such difference was seen with the 32 Hz modulated noise condition.

- There was a significant difference between the two modulated masking noise condition (16 Hz and 32 Hz) at both at 0 dB and -5 dB SNR.
- There was a significant difference in the performances between the two SNRs (0 dB and -5 dB).

SUMMARY AND CONCLUSION

Researches over the years have been highlighting the poor speech intelligibility of individuals in the presence of noise (Carhart, Tillman & Greetis, 1969; Miller, 1947; Miller & Licklider, 1950). Wagener and Brand (2005) found fluctuating noise affected speech intelligibility to a greater extent when compared to continuous noise. In 2007, Smits and Houtgast examined the effect of temporally fluctuating noise on speech intelligibility. They reported that the masking depended upon the rate of modulation of the noise. They found with lesser modulation (16 Hz) rates, release of masking to be more hence better intelligibility.

The aim of the study was to compare the speech identification scores for normal hearing individuals in different listening condition (Quiet, continuous noise, 16 Hz modulated noise and 32 Hz modulated noise) at different SNRs (0 dB and -5 dB). The study was carried out on 30 normal hearing Oriya speaking individuals. Routine hearing evaluation was initially done to confirm the presence of normal hearing. The Screening checklist for auditory processing (SCAP) developed by Yathiraj and Mascarehans (2002) was administered to rule out any central auditory processing disorder. Speech identification scores were obtained for all the four listening conditions at two SNRs. Oriya monosyllabic PB words developed by Behera and Yathiraj (2004), was used as the speech material. The obtained scores were also converted to rau scores to remove the non-linearity seen in the speech identification scores. All the scores (raw and rau) were analyzed using two-way repeated measure ANOVA and paired ‘t’ test. The statistical analyses results showed the following:

There was no significant difference between the speech identification scores got in the continuous noise masking condition and the two modulated masking conditions at the 0 dB SNR condition. However, there was a significant difference between the speech identification scores got in the continuous noise masking condition and the 16 Hz modulated masking conditions at the -5 dB SNR condition. As expected, no such difference was seen between the continuous and the 32 Hz modulated masking condition. There was a significant difference between the two modulated masking noise condition (16 Hz and 32 Hz) at both at 0 dB and -5 dB SNR. In consonance with the earlier reported literature, there was a significant difference in the performances between the two SNRs (0 dB and -5 dB).

Implications

The following are the implications of the present study:

- The results from the present study can be used as a reference to compare the performance of clinical populations such as those with peripheral hearing loss or those with a central auditory processing problem.
- The test material can be used to suggest the next line of management for those who get scores lower than what has been obtained in the present study. The management could either be in terms of using noise reduction algorithms, for those who require hearing aids, or in terms of noise desensitization training. The material can be used to plan a hierarchy of activities during an auditory training program.
- The data can be used to compare the performance of children with that of adults, which will throw light about the developmental process of listening in the presence of continuous and temporally modulated noises.

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