Original Research Article

The effect of environmental noise on speech perception of individuals with sensorineural hearing loss: a prospective observational study

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ABSTRACT

Background: This study was done to identify the effect that environmental noises have on speech perception of individual with sensorineural hearing loss. The objectives were to develop evidence-based approach to support the need for sophisticated technology and to choose the better one for daily listening purposes of Hearing-Impaired individual to obtain a speech perception score when environmental noises are used as competing signal.
Methods: The study was executed in three phases. In phase 1, developing a noise check list and recording the noise levels at different places by using sound level meter, in phase 2, analyzing the recorded noises into spectral and temporal distributions by using software and phase 3, testing the hearing loss individual's syllables in the presence of recorded noises.
Results: For 0 dB signal to noise ratio (SNR), the mean scores for white noise and temple noise were higher than for other noise types. The bus and auto noise conditions also showed significant difference in values between them. For +10 dB SNR, speech scores obtained for audiometry noise differed statistically from only restaurant and traffic noise. The traffic noise being the poorest differed statistically from all other noise types. On the other end of range, restaurant noise showed highest speech scores.
Conclusions: The overall the scores were a lot higher for only restaurant noise and noise of travel in auto. These showed effect of masking release and that hearing impaired are better able to understand conversations in these situations at least.

Keywords: Speech perception, Audiometry noise, Environmental noise, Signal to noise ratio, Pure tone average

INTRODUCTION

Speech is a primary vehicle of human social interaction. It occurs under an enormous range of different environmental conditions. Speech signal is always altered by background noise and other interfering signal such as reverberation, as well as imperfection of frequency and temporal responses of the communication channel.[1,2] Generally understanding of speech in noisy conditions will be poor and also individuals with hearing loss will have even more difficulty in understanding speech in noisy conditions.[1,2] The objective of the present study was to study the effect of noise on speech perception in mild to severe sensorineural hearing loss individuals in India and secondarily to comparing the normal speech perception score and speech perception score in selected noise, to develop evidence-based approach to support need for sophisticated technology and to choose the better one for daily listening purposes of a hearing Impaired (HI) individual, to develop a catalogue of real world noises, to prepare a normative data by using developed noise catalogue, to measure noise levels in minimum

different places by using sound level meter (SLM), to conduct acoustic analysis of noises and to obtain a speech perception score when real world noises are used as competing

Noise is defined as a sound signal that interferes with the detection or quality of another sound signal. (ASHA, 2017). People with sensorineural hearing loss have difficulty understanding speech, especially when background sounds are present.[3] A reduction in the ability to resolve the frequency components of complex sounds is one factor contributing to this difficulty. This shows that a reduced ability to process the temporal fine structure of sounds plays an important role.[4] Under natural conditions the distribution of noise across time and frequency is rarely uniform. Studies of speech perception in noise can be grouped according to the type of noise maskers used these include tones and narrowband noise, broadband noise, interrupted noise, speech-shaped noise, multi speakers babble, and competing voices.[5,6] Each type of noise has a somewhat different effect on speech intelligibility, depending on its acoustic form and information content.[7] Noise appears to create some kind of "roll over" effect to a normal hearer similar to that found in patient with sensorineural hearing loss in quiet condition.[8] The hearing impairment leads to limited auditory information which interns affects the perception. Depending on the site of origin of the loss and the degree to which it cut down the auditory information the perception of auditory stimuli will affect. Hence individuals with hearing impairment exhibit heterogeneous patterns of results. People with sensorineural hearing loss have difficulty understanding speech, especially when background sounds are present. A reduction in the ability to resolve the frequency components of complex sounds is one factor contributing to this difficulty.

METHODS

The study was done from July 2017 to June 2018, at an audiology and speech language pathology Centre and institutional ethical clearance was taken prior to the study. This study was implemented with an aim to find out "advance understanding of individuals with hearing loss listening needs in noisy listening situations and acoustic analysis of different noises."

Study design

The study was designed in three different phases. In phase 1, a noise check list has been developed and recorded the noise levels at different places by using SLM. In phase 2, the recorded noises have been analysed into spectral and temporal distributions by using software. In phase 3, the hearing loss individual's syllables have been tested in the presence of recorded noises.

Fifteen individuals or thirty ears with sensorineural hearing loss (SNHL) in 35 to 55 years of age range were included for obtaining speech perception test in noise.

Inclusion criteria

Degree of hearing loss or pure tone average of 0.5 kHz, 1 kHz and 2 kHz should be within 40 to 60 dB, the hearing loss in both the ears must be symmetrical and mother tongue of all the participant must be same were included.

Exclusion criteria

Sloping pattern hearing loss will be avoided, mother tongue not being the same and hearing loss other than SNHL will be avoided were excluded.

Two different signal to noise ratio (SNR) conditions were chosen to represent adverse listening condition and a favourable listening condition (0 dB and +10 dB SNR). Stimuli were 20 nonsense syllables in vowel-consonant-vowel order. Both vowels were /a/, and the C differed among 20 items. The consonants were common consonants of Hindi language. Recording of the 20 words were made using female (Hindi speaking). The recordings were evaluated by 3 people for quality and naturalness. The target word was embedded in a sentence to reduce inflection or emotional intonation. The Noise samples included were restaurant noise, temple noise, road traffic noise, traveling in Bus noise and auto noise and audiometric white noise. These were chosen as they were common to all hearing impaired who answered the checklist and also communication in these situations were very important to them. Audiometry evaluation and Immittance was done by using calibrated audiometer & middle ear analyser to know the individual's middle ear physiology. Those have bilateral moderate sensorineural hearing loss and bilateral 'A' type tympanogram were considered as participants for this study, later speech perception test was done by using prepared speech in noise (SPIN) test material with presence of different recorded environmental noises such as audiometric noise (white noise), traffic noise, temple noise, restaurant noise, in bus and in auto with different SNRs (0 dB and +10 dB SNR).

Statistical analysis

MANOVA is used for statistical analysis and it showed the major effect for 0 dB SNR condition, the type of noise on speech perception score to be statistically significant (at 0.00 level) but not for +10 dB SNR condition. The results showed significance values of .027 for noise types on all four tests of MANOVA.

RESULTS

For this study a total of fifteen individuals or thirty ears with moderate sensorineural hearing loss in the age group of 35-55 years were taken. The detail demographic data

and their clinical characteristics were presented in Table 1.

The results show at +10 dB SNR condition all subjects were able to get 65% and above scores irrespective of type of noise used for stimulus (Table 2). At 0 dB SNR, scores were down to 35% to 40% irrespective of type of noise (Table 3).

At +10 dB SNR only restaurant noise and noise in auto travel show very high scores (difference more than 15%) than that of audiometric white noise. At 0 dB SNR, the scores were poorer than 50% for all the type of noises.

For 0 dB SNR, speech scores obtained for audiometry noise (white noise) differed statistically from all other noise types. Temple noise also showed significant difference from all other type of noises. The mean scores for these two were higher than for other noise types (65% and 44% respectively). The mean scores for traffic noise was at 27.94%. Further the bus and auto noise conditions

also showed significant difference in values between them (mean values 27.1% and 33%).

For Both bus and auto, the road traffic noise was common, they affected speech perception scores differently. The speech scores do not depend on overall intensity level of noise but also on their frequency distribution characteristics. For +10 dB SNR, speech scores obtained for audiometry noise differed statistically from only restaurant and traffic noise. This is very different pattern from that of 0 dB SNR condition. Temple noise on the other hand was significantly different in its mean scores from traffic and bus noise types only. The traffic noise being the poorest (at 46%, mean score) differed statistically from all other noise types. On the other end of range, restaurant noise showed highest speech scores (at 80% mean scores), even better than audiometric noise. Scores for auto noise type differed from traffic noise alone, a pattern unlike that of 0 dB SNR. Again, better speech level than noise level does not ensure uniform improvement for all noise types.

Table 1: Demographic data and clinical characteristics of the study participants.

| Age/gender | Clinical characteristics (prior to study) | | | | |
| | Pure tone average (0.5 kHz+1 kHz+2 kHz)/ 3 in dB HL | | Tympanogram type | |
	Right ear	Left ear	Right ear	Left ear
37/M	40	45	A	A
42/F	45	45	A	A
53/F	46.6	48.3	A	A
36/M	43.3	50	A	A
45/M	51.6	53.3	A	A
49/M	40	43.3	A	A
54/F	55	53.3	A	A
39/F	41.6	43.3	A	A
43/F	50	46.6	A	A
43/M	45	48.3	A	A
46/F	41.6	43.3	A	A
37/F	40	45	A	A
48/M	45	46.6	A	A
53/M	46.6	53.3	A	A
51/M	50	55	A	A

All the ages are in years, M-male, F-female, kHz- kilo Hertz, dB- decibel, HL-hearing level.

Table 2: Mean and SD of speech perception test, for +10 dB SNR test condition.

	White noise	Traffic	Restaurant	Temple	Bus	Auto
Mean	74.54	46.47	80.29	70.58	54.11	68.82
SD	9.606	7.85	9.75	11.84	7.33	16.63
Range	25.00	25.00	40.00	55.00	25.00	60.00

Table 3: Mean and SD of speech perception test, for 0 dB SNR test condition.

	White noise	Traffic	Restaurant	Temple	Bus	Auto
Mean	65.24	27.94	31.470	44.41	33.23	27.06
SD	6.85	5.60	9.80	8.99	7.058	5.018
Range	20.00	20.00	30.00	35.00	30.00	15.00

DISCUSSION

Cruckley et al in their study of auditory ecology of school going children also noted that multi memory hearing aids may better suit the children in school. Their advantage may supplement the use of FM system as well. The noise level varied in level and frequency distribution when children moved from classroom to corridor to cafeteria or playground. And hearing aids were not able to keep up with the changes.[9]

Results of speech perception scores may help us to notice the listening situations which are hearing impaired friendly and which are not. The five real world noises were mixed with non-sense syllables and presented to hearing impaired for identification of the stimuli. The results were compared with that of standard audiometric speech noise scores.

The results showed at +10 dB SNR condition all subjects were able to get 65% and above scores across irrespective of type of noise used for stimulus. At 0 dB SNR, scores were down to 35% to 40%. As environmental noises tend to fluctuate in energy distribution over time, some amount of masking release may occur. Study done by Howard-Jones et al showed that hearing impaired were unable to use this modulation information and scores were not better when compared to their scores for narrow band noises.[10-12] This reduced masking release was also seen in the present study for most type of noises. Only restaurant noise and noise in auto travel showed better scores than that of audiometric noises at +10 dB SNR. At 0 dB SNR, the scores were poorer overall when compared to standard audiometric noises. The scores for restaurant and travel in auto showed effect of masking release and therefore hearing impaired are better able to understand conversations in these situations at least. +10 dB SNR probably is closer to real life level, people tend to be closer to the listener in these situations. At 0 dB SNR, these situations also showed poorer than 50% scores. This suggests that masking release happens if speech is relatively higher than background noise. People tend to move from one situation to another in a time span of day many times over. The challenges to the amplification devices due to this is quite complex. In a typical situation of a hearing-impaired subject traveling to the audiology facility (the institute where the study was conducted), the subject would be exposed to road traffic noise while waiting for bus and later to the noise in bus, and then the noise at the waiting area of the audiology facility. The subjects responding to the check list had indicated that in each of these situations following conversation was important to them. They were also unhappy with the performance of their present hearing aid in these situations. They were unable to listen to either understand the conversation of fellow passenger over and above that of background noise, neither they were successful in understanding the instructions or announcements of the public transport system. This highlight the relative difficulty the hearing-impaired

individual encounters in their most important transaction activity of everyday life. So far while designing the amplification devices, static listening situations are often considered i.e. home environment to be quiet, party to be noisy etc. and conversation importance also is under estimated. The assumption is that people talk one by one in any situation and the hearing-impaired subject is always facing talker. In a situation like buying a product in a shop, one need to hear to sales person across the counter. But often we need to hear people talking from the side or behind. The sales person also moves around. Similarly, in bus, while traveling, the co-passenger talks while sitting to the side of the hearing-impaired individual or from behind. Multi memory or multi programming hearing aids probably offer much needed flexibility. The additional feature of adaptable hearing aids, where in they detect the noise activity and adjusts gain parameters accordingly needs to be explored in detail in future. The algorithms these automatic hearing aids use to classify the acoustic ecology should be appropriate for auditory ecology of the subject. At the present time the classification would probably be inaccurate in identifying the situational acoustics. Most quiet surroundings may be noisy and when one moves noisy to severe noisy conditions, hearing aid may make inadequate changes to gain parameters. This probably make the technology unacceptable as disadvantages outweigh the advantages. Relative unfamiliarity of stimulus may also have added to the score differences seen. Studies with meaningful words or sentences may better be able to show the real-world difficulties experienced by the hearing-impaired adults. This is a preliminary study, an attempt at understanding real world difficulties of hearing-impaired adults. Auditory ecology, a novel idea to India may help us in future to understand the acoustical environment around us.

Modern hearing instruments typically offer some combination of frequency-gain adjustment, directional microphones, and digital noise reduction with the goal of providing better speech recognition and listening comfort/ tolerance in noise. While research has demonstrated that directional microphones can improve children's speech recognition in noise performance by Auriemmo et al and Gravel et al.[13,14] The use of DNR with children have not demonstrated any measurable improvement by Pittman et al and Stelmachowicz et al.[15,16]

CONCLUSION

The study was carried out in three phases. The first two phases were aimed at knowing the sounds in the environment important to hearing impaired adults and the third is a measure of speech perception in noise obtained on a group of hearing-impaired adults. The Speech perception in noise study showed that the scores of correct identifications of stimuli were statistically different for each type of environmental noise used. But, overall, the scores were a lot higher for only restaurant

noise and noise of travel in auto. These showed effect of masking release and that hearing impaired are better able to understand conversations in these situations at least. This study results were helpful in constructing a comprehensive list of auditory events important to hearing impaired adults.

Recommendations

Future studies may concentrate on knowing the relative advantages or accuracy of sound classification of automatic amplification devices. Datalogging is another feature, less explored in clinical audiology and dispensing audiology. This study may motivate researchers to look into this feature and the information it provides to audiologist in facilitating better programming methods. Studies may focus on developing a standardized list of sounds that are essential to hearing impaired in each of listening situations of their daily life.

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