SETTING OF CLASSROOM ENVIRONMENTS FOR HEARING IMPAIRED CHILDREN

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ABSTRACT

This paper aims to explain effects of acoustical environments in sound perception of hearing impaired people. Important aspects of sound and hearing impairment are explained. Detrimental factors in acoustic conditions for speech perception are mentioned. Necessary acoustic treatment in classrooms and use of FM systems to eliminate these factors are suggested.

Keywords: Hearing Impairment, Acoustics, FM System.

INTRODUCTION

Sound is a vibration in an elastic medium. It is a relatively simple form of energy, causing variations in pressure and alternations in direction of molecular movements within media. Sound, like all objective things, exists by definition and would exist even without any living thing to receive it or to be affected by it (Flindel, 1998; Nabelek, 1993; Yerges, 1969).

Sound originates with a source –some energy input of some sort; travels via a path- an elastic medium of some type; and reaches a receiver –usually the human body is the receiver of interest to us, although animals and equipment can be “receivers” too.

When sound reaches the human receivers it creates a response called *hearing*. Hearing is the principle *subjective* response to sound (Moore, 1997). Within certain limits of frequency and pressure, sound creates a sensation within the auditory system of humans and most animals.

In most animals and humans the ear is the perception organ of hearing. It receives sound vibrations on the ear drum, multiplies them by means of small bones arranged as levers in the middle ear, and transmits the vibrations through a fluid to the nerve endings within the inner ear. These nerves transmit an impulse to the brain which in a fraction of a second, analyzes and translates the impulse into a concept which evokes a mental or physical response (Moore, 1997; Staab, 1996).

Sound becomes, through experience and training, familiar symbols of a concept or situation. They give us information which orients us in our environment. However, in some cases the intactness of auditory system is impaired with some reason. Then we talk about *hearing loss***.** Hearing loss may occur in any part of the auditory system. Depending on the place and the degree of the loss, its effects vary from one individual to another.
Hearing losses may be broadly categorized into two main types. The first type *conductive hearing loss* occurs when there is a defect in the middle or outer ear. It reduces the transmission of sound to the inner ear. For example, fluid may be built in the middle ear as a result of infection or middle ear bones may be immobilized as a result of bone growth over the oval window. Sometimes a conductive loss is produced by wax in the ear canal. In general a conductive loss results in a more or less uniform hearing loss as a function of frequency; it can be regarded as resulting in a simple attenuation of the incoming sound. The difficulty experienced by the sufferer can well be predicted from the elevation in hearing thresholds. A simple hearing aid is usually quite effective in such cases and surgery can also be effective (Moore, 1997).

The second type of hearing loss is called *sensorineural hearing loss.* It mostly arises from a defect in the cochlea then it’s known as *cochlear loss*. However sensorineural loss may also arise as a result of defects in the auditory nerve or higher centers in the auditory system. Hearing loss due to neural disturbances occurring at higher point in the auditory pathway than the cochlea is known as *retrocochlear* loss. The particular difficulties experienced by the sufferer and the types of symptoms exhibited, depend on which part of the system is affected. Often the extent of the loss increases with the frequency. However difficulties experienced by the sufferer is not always well predicted from the hearing thresholds (Moore, 1997; Staab, 1996).

People with sensorineural hearing loss often have difficulty in understanding speech in noisy environments and the condition is usually not completely alleviated by a hearing aid. Most sensorineural losses can not be treated by surgery.

Sensorineural loss generally distorts perception of sound in certain aspects. It effects perception of loudness, pitch and discrimination (Boothroyd, 1993; Moore, 1997).

Loudness is the physical response to sound pressure and intensity. At any given frequency, the loudness varies directly as the sound pressure and intensity, but not in a simple straight-line manner. Perception of loudness depends on the listener and it is a subjective experience. A sound at the same intensity may not be perceived at the same loudness by two different listeners. In the case of hearing impairment loudness perception is more complicated.

Some hearing impaired people may suffer *loudness recruitment* which is defined as abnormal growth of loudness. These people hear sound comfortably up to a certain level, then a slight increase in intensity causes intolerable loudness which is not observed in normal ears. In normal ears loudness growth is rather a uniform process. Increase in intensity is perceived as a linearly increasing loudness, not a sudden change from comfort to pain (Moore, 1997; Staab 1996).

Loudness recruitment problem causes difficulties in hearing aid use. The hearing aids should be tuned using compression circuits. Even using compression does not overcome this problem completely, it only helps to minimize its effects to some extent (Boothroyd, 1993).

Pitch is the physical response to frequency. Frequency is defined as the number of cycles of a sound wave that occur per second. Low frequencies are identified as low in pitch; high frequencies as high-pitched. The frequency increases as cycle per second increases so does the pitch. Like in loudness, pitch perception is the subjective experience of an objective frequency. In normal ears cochlea is finely tuned to discriminate the differences in frequency, thus we can analyze and understand what we heard (Moore, 1997; Staab, 1996). The discrimination ability of the ear decreases when a sensorineural hearing loss is occurred. Therefore it is difficult for hearing impaired people to discriminate environmental and speech sounds especially in noisy situations. Difficulty increases as the degree of hearing loss increases (Boothroyd, 1993; Moore, 1997; Staab, 1996).

In a noisy background when we try to detect a signal, we use the auditory filter(s) to get the best signal-to-noise ratio. In a normal ear the auditory filters are relatively narrow, all of the background noise except a narrow band around the signal frequency are attenuated. In an impaired ear however the filters are broader. Therefore much more of the noise gets through the filter and the detectability of the signal is reduced. Thus background noise severely disrupt the detection and discrimination of sounds, including speech. This may partly explain for the great difficulties experienced by those with cochlear impairments in following speech in noisy situations such as parties and restaurants (Moore, 1997; Nabelek, 1993).

A second difficulty arises in the perceptual analysis of complex sounds such as music or speech. Perception of timbre or quality of a sound seems to depend upon the ear's frequency selectivity. When frequency selectivity is impaired, the ability to detect differences in the spectral composition of sound, hence timbre is reduced. Thus it may be more difficult for the impaired listener to tell the difference between vowel sounds or to distinguish different musical instruments (Flindell, 1998; Moore, 1997).

Although the use of hearing aids does not help correction of damaged frequency selectivity, it provides audibility of sounds to the hearing impaired.

Hearing aids work by collecting and electronically boosting sound from the environment. Hearing aids unlike human ear does not select the important features to get and understand speech signal. The most basic hearing aid amplifier works in response to an input signal which is sound of any type, that hits the microphone. (Boothroyd, 1993; Orchick, 1996). Although the development and use of digital technology in hearing aids made great improvement in filtering background noise, there is still much work to be done. Therefore some additional precautions must be taken to help hearing impaired people to get more clear speech signals while using the hearing aids.

ACOUSTIC ARRANGEMENTS

By acoustical arrangements we can shape the sound and control disturbing noises within the given environment.

The shape, dimensions and proportions of a space are major determinants of the acoustics of the space. The surfaces which bound a space affect and control the sound within the space (Yerges, 1969).

For a space in which critical listening is the major purpose of the room, the shape would evolve from acoustical requirements. For example a lecture hall must be designed to fulfill its acoustical function, all other considerations are secondary.

The room surfaces which reflect sound may either concentrate and focus the sound or diffuse or disperse it. Usually reflections which arrive at the listener's ear within 0.04 sec of the direct sound are desirable; they reinforce and enhance the direct signal. However reflections arriving later than this may cause undesirable effects (Boothroyd, 1993; Nabelek, 1993; Orchick, 1996; Yerges, 1969).

A major problem in almost any space is that of *echoes*, reflections which interfere with good hearing. Three types of echoes which are particularly important are:

1. Distinct, discrete sound, arriving at listener's ear sufficiently later than the direct sound to be heard as a delayed image of the direct sound (usually 0.06 sec or more –the time required for sound to travel about 2m. in air).
   Thus any reflecting surface more than 1m. from the source and facing the source may produce echoes.

2. "Flutter" echoes –the "rattle" or "buzz" sound resulting from discrete, rapid, multiple reflections between closely spaced parallel surfaces, but too rapid to be readily distinguished as images of the direct sound.

Usually surfaces must be more than 40 cm-1m. apart to cause flutter, although long or high corridors and similar spaces may produce serious flutter with less distance between surfaces (between walls or between floor and ceiling).

3. Reverberation –the persistence of sound after the source has ceased- resulting from the blending of many reflections into an indistinct but apparent "sea of sound". Reverberation may be desirable (as in the case of music), but it may seriously reduce the intelligibility of speech if it persist too long (Compton, 1989; Nabelek, 1993; Orchick, 1996; Yerges, 1969).

There is a range of optimum reverberation times for rooms of various sizes used for various purposes. The optimum reverberation time varies directly with the volume of the space and ranges from about 0.5 sec for small rooms to more than 2 sec for large spaces (Yerges, 1969).

Sound absorbing materials are used to reduce the intensity of each reflection so that the reflection do not interfere with hearing the direct signal clearly. Speech intelligibility normally requires reasonably short reverberation times usually under 1.5 sec in any space and preferably less than 1sec for lectures, drama and motion pictures.

Considering the difficulties which hearing impaired people suffer due to the hearing loss, adverse acoustical conditions in the listening environment will make it impossible for them to understand speech. The echoes, reverberation and noise will be collected by the hearing aid, boosted and delivered to the impaired ear which already have difficulties in frequency analysis to understand speech; and loudness growth to listen comfortably.

Correction of adverse acoustical conditions is not possible in every situation in which the hearing impaired has to live, but it is possible to make some arrangements in educational settings where hearing impaired children have to listen to the speech to learn.

Sound absorbing material can be used to control reverberation time in classrooms and high ceiling, long and hard walled corridors are better to be avoided in the school building. Use of carpets on the floors and soft materials covering the walls are suggested (Compton, 1989; Lewis, 1995; Nabelek, 1993; Orchick, 1996; Yerges, 1969).

It is easier to control acoustical conditions in small classrooms, severity of acoustical problems increases with the size of the room. In large spaces echoes, flutter, excessive reverberation, non-uniform distribution of energy, inadequate levels in areas away from the source, excessive concentration or focusing in some areas and similar faults are very common. On the other hand in small rooms, travel time of the sound wave from source-to-listener, source-to-surfaces-to-listener, and surface-to-surface is short; distinct echoes rarely occur and reverberation time is quite short. Background noise however can be almost as serious in small spaces as in large spaces (Yerges, 1969).

Background noise can be defined as any sound which may mask the target signal. In normal ears target speech signal should be at least 5 dBA above the background noise. The ratio of the target signal to the background noise is called the sound to noise ratio (S/N). In impaired ears S/N ratio should be at least 10-15 dBA to understand speech clearly (Compton, 1989; Lewis, 1995; Nabelek, 1993; Orchick, 1996; Yerges, 1969).

In a busy classroom, background noise may reach up to 60 dBA. This is an intensity level which can easily mask important spectral cues. In the noisy situations suggested solution is to speak closer to the microphone of the hearing aid. Speaking closer to the microphone helps to overcome background noise, and diffusion of sound energy occurs as a result of the distance between the speaker and listener. However in a classroom it is not possible for a teacher speaking always closer and directly to the hearing impaired student. Use of FM systems helps to solve problems which arise from the distance between speaker and listener in noisy environments.

FM SYSTEMS

All FM systems consist of two parts: a transmitter and a receiver.

The transmitter is used by the speaker. The microphone of the transmitter should be worn 15 cm. distance from the speaker's mouth. Increase in mouth-to-microphone distance will result loss in the sound energy.

Speech signals are collected by the microphone of the transmitter, converted to the electric signals then sent to the crystal oscillator in which the acoustic signals are transferred into FM radio signals. The radio waves are delivered to the receiver which is exactly tuned to the same channel as the transmitter. The receiver, worn by the listener, converts radio waves back to electrical signals and sends them to the hearing aid through an audio cable and audio shoes (Compton, 1989; Lewis, 1995; Nabelek, 1993; Orchick, 1996). Some receivers are directly connected to the hearing aids via the audio shoes. These type of receivers do not require the audio cable and smaller in size. Therefore they are more cosmetically accepted.

The advantages of FM systems can be summarized as follows:

- They provide up to 30 dBA sound-to-noise ratio so that the hearing impaired child has an easier access to the speech signal in noisy environments, like classrooms and lecture halls when compared to his/her hearing aids.

- The system can be used outside the classroom. Use of FM systems in educational activities like field trips, visits to museums, zoo etc. helps the hearing impaired children to follow the teacher's speech without any loss due to the distance. They hear it as the teacher speaks 15 cm. whatever the actual distance is.
- They could be used by the families at home and outside the home.
- When different frequency bands are used, they can be used in different classrooms in the school without any signal interference.
- Quality of the sound is not affected by electromagnetic fields (Compton, 1989; Lewis, 1995).

While using FM systems it should be noted that, FM systems are one-way transmitters. They only deliver the speaker's voice through the system. The child hears his/her voice and the voice of the others via the hearing aids. Therefore detrimental factors still exist for the other significant signals.

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