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Speech Intelligibility in Classrooms

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1. Introduction

Schooling is a fundamental part of our development in the early years of our lives. Schools and classrooms are the places where children learn, and most of this learning takes place by verbal communication. The acoustics of classrooms have a major effect on the intelligibility of speech used in the rooms, and therefore an effect on the pupils and teachers. This paper describes work carried out over the last three years, investigating the effect room acoustics have upon speech intelligibility in over seventy classrooms, and the effect this has on pupils and teachers.

2. Classrooms Today

The traditional style of teaching, where a teacher stands at the front of the room and instructs an entire class of quiet, orderly seated children is long gone. Occasionally this teaching style is used, more likely in secondary schools, but today's classrooms are busy, noisy places. Often small groups of pupils work independently on tasks, using discussion and interaction. The teacher will spend time circulating amongst the groups, spending time with each one to direct and advise. Most classrooms will now have at least one teaching assistant, who takes small groups for reading or other activities. All this activity in a classroom is bound to create noise.

If noise becomes too loud, or uncontrolled it can be unwelcome and even harmful. Noise causes stress and irritability and affects the behaviour and performance of both teacher and pupils[1,2]. Noise also interferes with speech communication, particularly for any pupils with hearing impairments, whether permanent or temporarily caused by a cold or ear infection. The high levels of noise, combined with poorly designed, reverberant classrooms, creates an environment which is detrimental to speech communication.

3. Classroom Acoustics Project

It is widely acknowledged that the two main factors which affect speech intelligibility in classrooms are background noise and reverberation times. There is some debate as to which has the most detrimental effect, noise[3] or reverberation time[4], but all agree that in order to improve speech intelligibility both need to be reduced to acceptable levels. There are UK government guidelines (Building Bulletin 87)[5], which recommend background noise levels of $40dB_{LAeq1hour}$ (30 dB for hearing impaired pupils) and mid-frequency reverberation times of 0.5-0.8 seconds (0.3-0.6 for hearing impaired pupils), but there is little mention of speech intelligibility.

This study found the average background noise level in acoustically untreated classrooms to be 44.7dB(A) when empty, 55.5dB(A) when occupied and 77.3dB(A) when the children are working. This is clearly in excess of the recommendations. The average reverberation time in untreated, unoccupied classrooms was 0.7 seconds. This does fall within the DfEE guidelines, but only for normally hearing pupils. It must be accepted that most classrooms contain some hearing impaired pupils and should be designed to the lower guidelines.

A selection of classrooms were then treated with acoustical ceilings (Absorber Class A) and the measurements were repeated. The average background noise level when empty reduced from 44.7dB(A) to 40.1dB(A), when occupied from 55.5dB(A) to 46.5dB(A) and when full of working pupils from 77.3dB(A) to 70.1dB(A). The average reverberation time also reduced from 0.7 seconds to 0.4 seconds, which is well within the DfEE guidelines for all pupils.

Speech intelligibility scores in all classrooms were obtained using the Speech Transmission Index (STI) rating. Measurements were taken at every seat location in occupied silent rooms and an average score was produced for each room. The STI has been used by various researchers as a guide to speech intelligibility and it measures the reduction of a signal which undergoes fluctuations when travelling from source to receiver. The modulated transfer function, measured in each octave band, is converted into a figure between 0 and 1, where 1 indicates that 100% of the syllables in speech are understood and 0 indicates that no speech will be understood. Whilst STI measures the quantity of speech arriving at a listener's ear, the Percentage Articulation Loss of Consonants (%ALcons) is an indication of speech quality. The recommended %ALcons for excellent intelligibility in a room where children are listening to speech is no more than 5%.

The classrooms with acoustical treatment, resulting in lower background noise levels and lower reverberation times, had much improved speech intelligibility than those with more noise and reverberation. Table 1 shows the improvement in speech intelligibility scores, STI and %ALcons after acoustical treatment.

	UNTREATED	TREATED
STI SCORES (0=bad, 1=excellent)	0.501	0.700
%ALCONS (100%=no speech understood) 0%=all speech understood)	13.7	4.6

Table 1. Effect of acoustic treatment on speech intelligibility in classrooms

Whilst objective measurements confirmed that acoustical treatment can drastically improve speech intelligibility, a subjective test was devised to confirm the actual effect on pupils themselves. A listening test, Word Intelligibility by Picture Identification (WIPI)[6] test was carried out on a number of groups in classrooms before and after treatment. Once again, in all cases, the intelligibility of speech improved after acoustical treatment.

	UNTREATED	TREATED
CONTROL	96.7%	97.5%
QUIET CLASSROOM	94.2%	97.5%
PUPILS WORKING	57.2%	67.0%

Table 2. Percentage of words correctly identified in the WIPI test (Average scores).

The subjective test confirmed that pupils hear and perform better in classrooms with appropriate acoustical conditions.

4. Solutions to The Problem of Poor Speech Intelligibility

Across the world, there is a large divide between opinions for solutions to poor speech intelligibility in classrooms. Most experts agree that noise and reverberation times are detrimental factors and the solution is to increase the signal to noise ratio. This is where opinions tend to differ. Many people are in favour of increasing the signal, using amplification or speech reinforcement systems[7] while others believe the only solution is to lower the noise by treating the room itself[8].

There are advantages and disadvantages in both cases, practical and financial. However, the results of this project tend to suggest that it is possible to improve the speech intelligibility in classrooms without using any form of amplification. The advantages of treating the classroom, or building a new classroom with optimum acoustical conditions are numerous. Firstly, acoustical treatment does not rely on a power supply to work and once installed, little can go wrong with it. Secondly, "in an acoustically good room, speech is perceived uniformly around the room without electroacoustic amplification"[8]. In a classroom, communication is rarely just from teacher to pupil. It is often pupil to pupil or pupil to teacher. In the busy, group orientated classes, described earlier, an amplification system would purely raise the noise levels in the room, increasing distraction and disruption in the groups working on separate activities. This is even more the case in open-plan classrooms where increasing the noise levels in one classroom, will directly affect the class(es) in adjoining areas.

In some cases, speech reinforcement and amplification systems may be useful, for example in large assembly halls. However, during the course of this project, several multi-purpose school halls were treated acoustically with impressive results. A school in Hampshire, England had a recently constructed hall with a reverberation time of 2.14 seconds. Amplification systems were regularly used for school assemblies, plays etc. After acoustical treatment, the reverberation time decreased to 0.59 seconds. For the first time, speech in the hall could be understood clearly with no need for amplification.

5. Conclusion

There is much controversy over the best solution to the problem of poor speech intelligibility in classrooms. The amplification vs. acoustics debate continues world-wide, with experts seeking the perfect solution for the average classroom. However, just as there is no average child, there is no average classroom. Each varies according to its design, size, occupants, use and changes from day to day and year to year. One simple solution cannot be sought, reached and applied. Every classroom needs careful consideration, whether existing or planned. In most cases the acoustics can be improved, but in others the only solution may be to install an amplification system. In the opinion of the authors, the first action is to design or adapt classrooms so they have a low background noise level and a short reverberation time, which should then produce intelligible speech and a comfortable working environment for teachers and pupils. Then, if problems of unintelligible speech still exist, amplification should be considered. We can not, and should not, dismiss either approach and the aim of each is the same - improving speech intelligibility in classrooms.

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