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Speech Intelligibility in Classrooms

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1. INTRODUCTION

The 1981 Education Act [1] states that Special Needs pupils must not be excluded from mainstream schools. In theory, this is an excellent idea as all kinds of children benefit from integration. However, in practice, this process of integration is not so valuable if the schools are not prepared for the needs of every child in the school. Just as there are many types of special needs and disabilities, there are many types of barriers preventing the typical mainstream classroom from becoming an accessible and successful learning environment for all.

A recent report of special educational needs provision in Scotland[2] states that all children must receive an "education appropriate to their needs" and that "integration means placing children with learning difficulties in mainstream schools and providing adequately for them". A child must be taught in the "least restrictive environment" regardless of their needs.

This research project is focusing on improving one of the most fundamental aspects of school buildings, that is, acoustics. More children with hearing impairments are being integrated into mainstream classrooms, and if these classrooms are not excellent listening environments an increasing percentage of children will be disadvantaged.

2. PREVIOUS RESEARCH

Very little work has been conducted in Britain on the acoustics of classrooms. However, around the world many researchers have identified specific acoustical problems in schools. Problems commonly found include; " the acoustical conditions in the majority of classrooms studied were unacceptable" (New Zealand, 1994)[3], "the measured classrooms include a reasonable range of acoustical problems" (Canada, 1995)[4], "background noise levels (L_{90}) during instruction were high. Equivalent continuous noise levels (L_{Aeq}) were high. Most classrooms are too reverberant." (Finland, 1991)[5], and "the acoustic qualities of most of our classrooms are too poor" (Denmark, 1994)[6].

However, despite the range of unsuitable classrooms discovered, there are few suggestions on how to improve the acoustics, especially speech intelligibility, within classrooms.

Results from a pilot study on the acoustics of classrooms, conducted by Heriot-Watt University, support these findings. Forrester High School in Edinburgh has a Hearing Impairment Unit which, along with the rest of the school, suffers greatly from external and internally generated noise. Noise sources have been identified as road, rail and air traffic, building services noise and general noise created by the school going about its daily business.

The results of the study show that over 75% of the rooms tested experienced noise levels above the acceptable background noise levels for school classrooms, and 66% exceeded the recommended reverberation times[7].

Further research work at Heriot-Watt University identified parameters which affect speech intelligibility in rooms are shown in Figure 1 below [8].

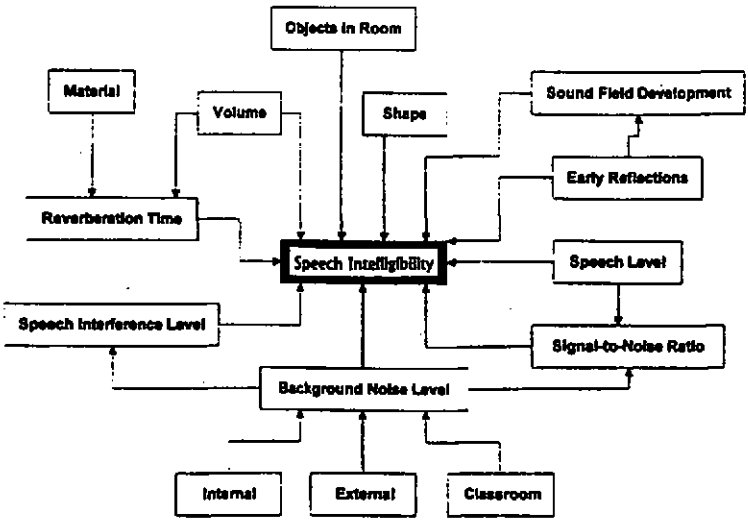

Figure 1: Parameters Which Affect Speech Intelligibility

Speech intelligibility is not the only factor affected by background noise in classrooms. It has been widely proven that noise affects performance, especially the higher mental thought processes such as those used in problem solving[17] and short and long term memory[14] [15]. So even when speech is not being used, the children and their education could still be affected.

4. MEASUREMENTS AT FORRESTER HIGH SCHOOL

The upper recommended values for reverberation time and background noise levels in classrooms for normal and hearing impaired school pupils are shown in Tables 1 and 2 below and any value below these will help to improve listening conditions [7][16].

	RECOMMENDED VALUES (NORMAL HEARING PUPILS)
REVERBERATION TIME (AT 500 Hertz)	0.75 SECONDS
BACKGROUND NOISE LEVEL (AVERAGE SIZED TEACHING GROUP)	BNL 35

Table 1: Recommended Values (RT & BNL) For Normal Hearing Pupils

	RECOMMENDED VALUES (HEARING IMPAIRED PUPILS)
REVERBERATION TIME (AT 500 Hertz)	0.5 SECONDS
BACKGROUND NOISE LEVEL (AVERAGE SIZED TEACHING GROUP)	BNL 30
BACKGROUND NOISE LEVEL (SMALL GROUPS)	BNL 25

Table 2: Recommended Values (RT & BNL) For Hearing Impaired Pupils

The background noise level and reverberation times for different conditions within the Hearing Impairment Unit rooms and other classrooms, which are used by normal hearing and hearing impaired school pupils, are shown in Table 3.

	BNL UNOCCUPIED	BNL OCCUPIED	RT(s) UNOCCUPIED AT 500 Hz	RT(s) OCCUPIED AT 500 Hz
H.I.U. (Front Room)	25	40	0.19	0.18
H.I.U. (Back Room)	30	40	0.23	0.22
Classroom 22	35	50	0.58	0.53
Classroom 23	35	70	1.36	1.01
Geography (A10)	30	60	-	-
Science Room 2	50	65	1.32	0.41
Drama Room	30	-	0.72	0.64

Table 3: BNL's and RT's For Unoccupied and Occupied Classrooms

An analysis of the reverberation time results, shown in Tables 4 and 5 indicate that the majority of the rooms fail to meet the criteria, even although there is a special unit within the school assisting pupils who have a hearing impairment.

	RECOMMENDED RT	RT UNOCCUPIED	CRITERIA SATISIFED	RT OCCUPIED	CRITERIA SATISIFED
Classroom 22	0.75	0.58	✓	0.53	✓
Classroom 23	0.75	1.36	×	1.01	×
Science (2)	0.75	1.32	×	0.41	×
Drama Room	0.75	0.72	✓	0.64	✓

Table 4: Recommended and Measured RT's for Normal Hearing Pupils

	RECOMMENDED RT	RT UNOCCUPIED	CRITERIA SATISIFED	RT OCCUPIED	CRITERIA SATISIFED
H.I.U. (Front Room)	0.5	0.15	✓	0.18	✓
H.I.U. (Back Room)	0.5	0.23	✓	0.22	✓
Classroom 22	0.5	0.58	×	0.53	×
Classroom 23	0.5	1.36	×	1.01	×
Science (2)	0.5	1.32	×	0.41	×
Drama Room	0.5	0.72	×	0.64	×

Table 5: Recommended and Measured RT's for Hearing Impaired Pupils

5. AIMS OF CURRENT RESEARCH PROJECT

The Department of Building Engineering and Surveying has recently commenced work on an EPSRC funded two year research project entitled Speech Intelligibility in Classrooms.

The first aim of this project is to establish the present acoustic properties of a range of classrooms used by primary school pupils who may have normal hearing or are hearing impaired. There are four main aspects of speech intelligibility testing that will make our research differ from previous research in this area:

1. Children as subjects: it has been shown that children are more affected by poor acoustics than the majority of adults. All children, particularly those with hearing impairments, require lower background noise levels and reverberation time to achieve optimum results[40]. Therefore, speech intelligibility tests to identify problems within classrooms need to be conducted with children of the appropriate age range as subjects.

2. Occupied rooms: as a classroom is occupied by children during the day, it seems reasonable to test the acoustics of a classroom when it is occupied by children. An occupied room will produce different results to an empty one, particularly those with a long reverberation time. The effect is also more noticeable if the teacher is speaking whilst seated. A classroom which is unsuitable for listening when empty, may be acceptable once occupied, or vice versa.

3. Binaural listening: much research has been conducted using monaural listening conditions. We aim to test children in their natural listening environment, using both ears in a normal every day class situation.

4. Words in carrier sentences: the speech intelligibility of a word is affected by those words which precede it. Therefore, a child may be able to identify a single word when presented with it, but if the target word is contained in a sentence, it may be smeared by previous words. If test words are located within carrier sentences, a more realistic representation of the amount of words a child can hear in a given room will be obtained.

A variety of tests will be applied to each of the sixty or more classrooms studied. Background noise levels, Noise Criteria ratings, STI (full, male and female) and RASTI values/ratings and reverberation times will be measured for each of the classrooms tested, using the Maximum-Length Sequence System Analyser (MLSSA) software as the measuring system. These will be used to identify acoustical problems in the classrooms and to develop possible remedial treatment to create improved speaking/listening environments.

As well as the above methods which measure the acoustic parameters of the classroom, the WIPI (Word Intelligibility Picture Identification)[17] test will also be used to take into consideration the effect of noise on the human aspect of speaking and listening. This test, which is pictorial, eliminates the effect of literacy and oratory skills and requires an immediate response, limiting the variable use of children's memories. The words are phonetically balanced and within the vocabulary of most children over the age of five.

The second goal is to develop a design guide on how to improve the acoustics of classrooms using speech intelligibility of the space as a measurable parameter. These guidelines will be of practical use for architects and builders designing new schools and existing schools requiring modifications.

The guidelines will suggest noise control plans into account such factors as: use of glazing, carpets, acoustic tiles, door pockets, improved heating and ventilation systems, external landscaping, layout of school rooms and appropriate planning of school timetables.

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