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How classroom acoustics affect the vocal load of teachers

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Abstract

In the UK the document BB93 Acoustic Design of Schools provides design guidance for refurbished and new classrooms. Traditionally, school acoustic design in the UK is concerned with the needs of the listener, rather than the voice ergonomics of the speaker. However, a recent survey undertaken by London South Bank University (LSBU) indicated that over 65% of the surveyed teachers had experienced voice problems during their career. This supports other studies suggesting that teachers have a significantly higher incidence of voice problems than the general population.

In an effort to better understand the influence of classroom acoustic design on teachers' speech LSBU is undertaking measurements of teachers' voices in different classroom types. An Ambulatory Phonation Monitor (APM) is used to measure voice parameters (including the average speech sound level, fundamental frequency and phonation time) directly from the skin vibrations in the neck, thus eliminating the effects of other noise sources in the environment. The rooms involved are acoustically benchmarked separately to enable relationships between the voice data and acoustic parameters, such as unoccupied ambient noise levels and reverberation times, to be investigated. This paper will present the results of the field measurements to date, and discuss some of the findings.

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1. Introduction

The requirement for appropriately low noise levels and suitable speech intelligibility in teaching rooms is now widely acknowledged as being essential for effective pupil learning.

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In the UK there have been school guidance documents on acoustics for many decades. A new edition of Building Bulletin 93 (BB93), containing acoustic performance standards for schools, was published in December 2014 [1]. This document contains updated requirements for acoustics in educational spaces, focusing primarily on the importance of the pupil hearing the teacher. Previous studies [2] indicate that the teaching profession has a greater prevalence of voice issues when contrasted with the general population; however the acoustic design of classrooms does not normally consider the voice ergonomics for the teacher.

In practical terms, for school design, there is a need for guidance on considering the voice in classrooms, and whether passive room design (i.e. not relying on speaker systems) can influence voice parameters.

A major change between the 2003 and 2014 editions of BB93 is that, whereas previously there was no minimum standard for refurbishment other than to achieve (where practical) the new build standard, the revised document specifies criteria for both new and refurbished school buildings. Furthermore, where a design team seeks relaxations or variations in the criteria because the acoustic requirements conflict with other factors in the overall design such as thermal, sustainability, structural, aesthetic or financial considerations, and any alternative performance standards must now meet the refurbishment standards.

The main BB93 (2014) requirements for primary and secondary school classrooms are shown in Table 1 for information:

Table 1. Acoustic requirements under BB93 for classrooms

Pupil age	Unoccupied ambient noise level $L_{Aeq,\ 30\ minutes}$ dB		Reverberation time T_{mf} (seconds)	
	New classroom	Refurbished classroom	New classroom	Refurbished classroom
Primary school (children aged 5-11)	≤ 35	≤ 40	≤ 0.6	≤ 0.8
Secondary school (children aged 11-18)	≤ 35	≤ 40	≤ 0.8	≤ 1.0

BB93 describes the acoustic requirements in Table 1 as good minimum standards and states that on occasion higher standards will be necessary.

T_{mf} referred to in Table 1 is the mid-frequency reverberation time, which is the average of the reverberation times at the 500, 1000 and 2000 Hz octave bands. The reverberation time values are to be achieved in finished rooms, furnished for normal use, but unoccupied.

The internal noise levels exclude noise generated by teaching activities in the school itself and apply during normal teaching hours; these are typically 09:00-15:30 hours in UK.

It should be noted that these requirements are not retrospective and apply to new construction and refurbishment projects only rather than to existing classrooms, however BB93 remains the most suitable guidance for assessing existing school buildings.

To better understand the influence of classroom acoustics on different voice parameters, classroom measurements have been carried out of the voices of teachers working in classrooms of different types, with a range of acoustic conditions.

2. Methodology

2.1. Voice measurements

To measure various speech parameters for teachers working in classrooms with different acoustic conditions, a method for field measurements has been developed. This methodology is described in detail in reference [3]. It includes measurements during lessons of general noise levels in the classroom, including those due to the teacher's voice and all other noise sources; and measurements of the teacher's voice level only whilst teaching, using an ambulatory phonation monitor (APM).

The APM is a device which measures vibrations from speech using a small accelerometer fixed to the skin over the speaker's sternal notch. The APM is calibrated prior to the measurements using a calibrated microphone mounted at a fixed distance (0.15 metre) from the mouth allowing a speech level to be calculated from the measured acceleration.

Following calibration the participant wears the accelerometer for their working day attached to a small unit on their waist. The APM monitors a number of speech parameters including average sound pressure level (Lp) and the fundamental frequency of the voice (f0). In addition the APM measures the total phonation time, which is the total speaking time during the measurement excluding pauses, and the phonation percentage which is the proportion of the measurement period for which the teacher was speaking. The APM unit is supplied with proprietary software which carries out analysis as well as allowing the raw acceleration data and transfer functions between acceleration and Lp to be exported for analysis in other software.

The voice levels of 20 teachers, of whom 14 were female and six were male, were measured. The balance of gender reflects the profession as a whole, 74% of UK teachers being female[4]. Four of the participants taught in secondary schools (pupils aged 11-18 years), and 16 in primary schools (pupils aged 4-11 years).

2.2. Classroom acoustics measurements

Acoustic measurements were undertaken of the empty classrooms in which the participating teachers taught. These included measurements of unoccupied internal ambient noise levels as well as reverberation time measurements to determine the T_{mf} value.

The classrooms involved in the study were chosen to be representative of the range of UK classroom stock, ranging from those constructed in the late 19th Century with high ceilings, large volumes, single glazing and no acoustic treatment, to classrooms refurbished to 2003 BB93 standards in recent years. Figure 1 shows examples of older and more recent classrooms measured in this study

Figure 1. Typical UK classroom constructed in (a) the late 19th Century; (b) the late 20th Century.

3. Results

Measurements have been undertaken for 20 participants, 14 female and 6 male teachers. The research study was approved by the University Research Ethics Committee under approval UREC 1283.

The results of the voice and acoustic measurements are summarised in Table 2

Table 2. Voice Measurement Results.

Participant gender	School Type	Phonation %	Average Lp at 1m from mouth	Unoccupied ambient noise level L_{Aeq} dB	Reverberation time Tmf (seconds)
Female	Secondary	22	57	28	1.0
Male	Secondary	16	62	23	0.4
Male	Secondary	18	60	24	0.3
Female	Secondary	13	66	27	0.9
Female	Primary	26	63	29	0.5
Female	Primary	28	72	37	0.6
Female	Primary	26	75	38	0.9
Female	Primary	23	65	32	0.9
Female	Primary	18	68	32	0.8
Male	Primary	13	64	30	1.0
Female	Primary	18	58	29	0.4
Female	Primary	18	71	30	0.4
Female	Primary	18	79	35	0.7
Male	Primary	22	61	37	0.8
Female	Primary	25	76	35	0.5
Female	Primary	26	75	29	1.1
Male	Primary	19	70	30	0.4
Female	Primary	31	78	26	0.4
Female	Primary	27	62	28	0.3
Male	Primary	15	63	28	0.7

It can be seen that the participants measured in this study taught in classrooms with a broad range of acoustic conditions: the T_{mf} varied from 0.3 to 1.1 seconds and the unoccupied internal noise levels from 23 to 38 dB L_{Aeq}.

Of the 20 classrooms seven had internal noise levels above the internal noise level criterion for new classrooms, although all measured classrooms complied with the criterion for refurbished classrooms. In terms of reverberation time ten classrooms did not meet the new build criteria, and four did not meet the refurbished classroom criteria. Two teachers taught in rooms that did not comply with the most onerous standards (those for new build) for both parameters.

Figure 2 shows the distribution of speech levels based on BS ISO 9921-1 categories of vocal effort [5].

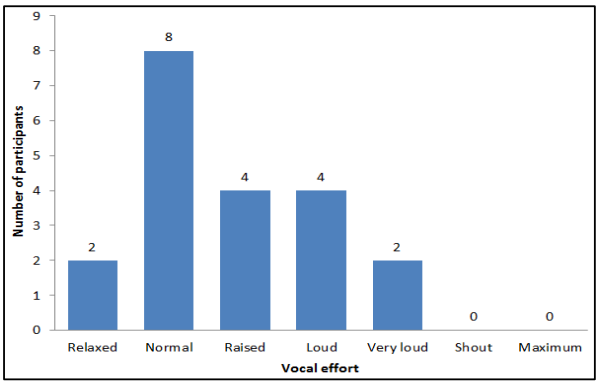

Figure 2. Vocal effort of participants.

The distribution of vocal effort shows that 50% of the participants spoke at a speech level in the 'normal' or 'relaxed' categories (defined under BS ISO 9921-1), and that the remaining 50% had voice levels in the 'raised', 'loud' and 'very loud' ranges. Voice levels have been compared with the measured room acoustic parameters. There was a moderate positive correlation between voice level and unoccupied ambient noise level (Spearman's $r = 0.43$, $p < 0.05$) but no correlation between voice level and reverberation time. Figure 3 shows a scatter plot of voice levels against unoccupied ambient noise levels.

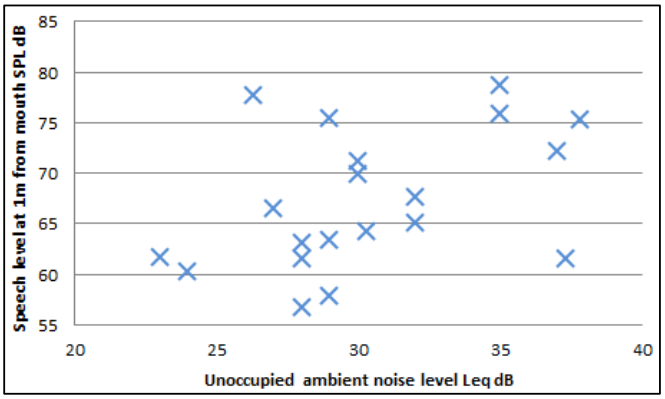

Figure 3. Scatter plot of voice level and unoccupied ambient noise level

4. Conclusions

The proportion of the working day for which the participants spoke had a mean value across the sample of 21% (range 13%-31%). This is in agreement with previous research [6] which found that the phonation percentage for teachers was typically 21%, whereas for office workers it was 7%. This highlights a possible risk factor associated with voice problems in teachers, namely intensive use of the voice, as illustrated by a high phonation time during the working day. A second risk factor is suggested by the voice levels measured, which showed half of the participants speaking at elevated speech levels. The combination of these two factors may explain the high incidence of voice problems among teachers.

The measurement data analysis to date shows a positive correlation between internal ambient noise levels in classrooms and the speech levels of teachers working in those rooms.

It has previously been found that secondary school lesson noise is related to unoccupied noise level [7], with higher unoccupied noise levels resulting in higher classroom noise levels. Hence it may be assumed that higher unoccupied levels will lead to teachers needing to increase their vocal effort to be heard. This reinforces the importance of suitably low internal noise levels in classrooms not only for good speech intelligibility and to avoid the excitation of the reverberant field in the room, but also to reduce the required signal to noise ratio for the teacher's voice. Lower unoccupied and resultant occupied noise levels indicate that average speech levels will be reduced when the indoor ambient noise level is lower.

It is notable that the majority of the teachers in this study taught in classrooms which complied with the most onerous current criteria for new build classrooms. All the teachers taught in classrooms which complied with the standard applied to newly refurbished classrooms, yet even within that range there appeared to still be an influence on speech levels from unoccupied ambient noise levels.

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