MADRID
inter.noise 2019
June 16 - 19
NOISE CONTROL FOR A BETTER ENVIRONMENT

Measuring classroom acoustics with a systematic approach

Greta Minelli[1], Arianna Astolfi[2], Giuseppina Emma Puglisi[3], Silvia Murgia[4], Louena Shtrepi[5]
Department of Energy, Politecnico di Torino
corso Duca degli Abruzzi, 24, 10129, Torino, Italy

Andrea Prato[6]
Istituto Nazionale di Ricerca Metrologica - INRiM
Strada delle Cacce, 91, 10135 Torino, Italy

Tiziana Sacco[7]
Department of Neuroscience, Università degli studi di Torino
Via Cherasco, 15, 10126 Torino, Italy

ABSTRACT

Classroom acoustics has major implications in speech production, in speech intelligibility and in the learning process. Excessive noise levels and long reverberation times, in fact, can degrade the speech production and propagation in classrooms thus can impair an effective listening. Recent studies have highlighted the need of guaranteeing optimal conditions in classrooms to enhance the capability of students to understand a vocal message and to reduce the vocal effort required to teachers. However, a lack in the available literature exists with respect to an effective protocol of acoustic measurements to be performed in classrooms so that accurate comparisons can be performed across several classrooms, which present different architectural, thus acoustics, features. This work is an attempt to identify the best guidelines for practitioners, architects and acousticians when performing acoustic measurements in classrooms. A protocol to accurately and effectively measure the acoustic parameters in classrooms is proposed, as well as to compare results across different types of environments.

Keywords: Intelligibility, learning evironments, measurements
I-INCE Classification of Subject Number: 72

[1] gretminelli@polito.it
[2] arianna.astolfi@polito.it
[3] giuseppina.puglisi@polito.it
[4] silvia.murgia@studenti.polito.it
[5] louena.shtrepi@polito.it
[6] a.prato@inrim.it
[7] tiziana.sacco@unito.it

1. INTRODUCTION

The transmission of information from a teacher to a student can be compromised where the acoustics of the classroom in which the learning process takes place is not optimal. On the teacher's side, there is evidence in the possible problems related to voice production and vocal fatigue [1]. On the student's side, there are many scientific studies that have proven the negative effect of noise on speech intelligibility and academic performance. Moreover, the younger the learners are, the more they are affected by the acoustic conditions of the classrooms [2].

D.M. 11/01/2017, "Adoption of Minimum Environmental Criteria (CAM) for interior furnishings, construction and textile products" indicates the acoustic requirements for school buildings in case of construction and renovation. Referring to indexes and limit values presented in UNI 11367 and UNI 11532 (in updating) standards, D.M. 11/01/2017 sets new references based on technological changes found in recent years.

2. METHODOLOGY

2.1 Students, classrooms and schools

The present study involved 209 primary school children distributed in 12 classes belonging to 7 different schools located in the metropolitan area of Turin. The 12 classrooms differed in terms of construction time, location, geometry and orientation. Their volume ranged from 120 m^3 to 290 m^3 and their height from 3.0 m to 5.3 m

2.2 Equipment

Measurements were carried out in occupied condition with a calibrated NTi XL2 sound level meter, a "NTi Audio TalkBox" source and a clapperboard. Measurement set-up and surveys execution took around one hour, meanwhile children responded to a questionnaire about noise and well-being at school. The output of the measurements and the questionnaires were returned to the teachers of each class on easily interpretable reports.

2.3 Measurements: protocol and parameters

Figure 1 shows the measurement positions for the characterization of each occupied classroom. According to a protocol specially designed for this work, measurements have been performed for two source positions (S1 and S2), both centered on two orthogonal walls of the classroom and at least 1 m from them. A maximum of 10 microphone positions were selected case-by-case.

For the evaluation of the noise level (L_N), L_{Aeq} and L_{A90} parameters based on 3 minute acquisition intervals were evaluated. Measurement points varied from a minimum of two and a maximum of three, corresponding to positions 5, 2 and 6 in Figure 1. Noise measurements were carried out when children in silence or performing group activities.

For the evaluation of the level of the vocal signal (L_S), the source emitted a voice signal with "normal" effort, corresponding to 60 dB (A) at 1 m in anechoic conditions in accordance with the UNI 9921 standard. The microphone was settle at 1.5 m height from the floor and at a distance of 1 m from the source; measurements in the control position and in position 1, 2, 3 and 6 were carried out when source S1 active, while positions 2, 4, and 6 referred to the activation of source S2.

Speech intelligibility was measured by various indices including the STIPA index (-), in accordance with IEC 60268-16. The microphone positions are those described for the measurement of the previous signal level. In accordance with the UNI 11367 standard, the optimum STIPA is greater than or equal to 0.60.

Clarity C50 (dB), is an intelligibility index obtained from the impulse response of three sweep signals emitted from the source and recorded at each measurement point. The microphone positions were those described previously for the measurement of the signal level. According to the UNI 11367 standard, the C50 is averaged between 500 and 1000 Hz (C50,0.5-1kHz) and its value must be greater than 0 dB.

Useful to detrimental energy ratio U50 (dB) is an intelligibility index that considers both the effect of the acoustics of the environment and the effect of the signal-to-noise ratio; it is calculated by the ratio useful energy / harmful energy [3]. This index is obtained from the C50, from the level of the signal in the different microphone positions, and from the level of the averaged background noise in occupied conditions with children in silence. As C50, the calculated value of U50 is then averaged between 500 and 1000 Hz ($U50_{0.5\text{-}1kHz}$). The optimal value is greater than 1 [3].

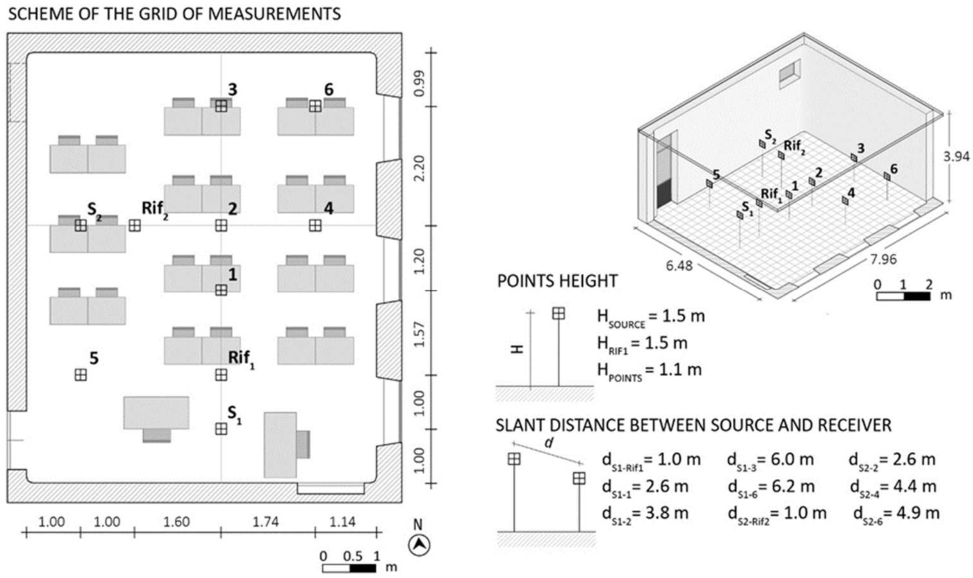

Figure 1 – Measurement configuration of a classroom sample.

For the intelligibility index "Signal to Noise Ratio" SNRA (dB) the effect of noise in the environment weigh more than that of the sound tail. It is calculated as a difference between the signal level and the noise level in the different measurement positions, both A weighted. The level of the background noise is the average value in occupied classroom conditions when children in silence. The optimal value is more than 15 dB [4].

The measurement of the reverberation time T30 or T20 (s) was carried out with the clapperboard, according to the UNI EN ISO 3382-2 standard. Measurements were repeated at different points, then data were averaged to obtain a single spatial value: this value was averaged between 250 Hz and 2 kHz too, in accordance with DIN 18041, that reports also the optimal values.

Background noise level and reverberation time measurements were also performed in unoccupied classrooms. The measurement positions for the background noise level are 2, 5 and 6 in Figure 1. The averaged background noise levels in the unoccupied classroom were compared with the limit value of 45 dB (A) reported in the D.P.R. March 30, 2004, n. 142, on road traffic noise. Building Bulletin 93 in the United Kingdom set the limit values to 35 dB (A) in the case of new buildings and to 40 dB (A) for renovations. The reverberation time values were compared with the optimal ones identified in accordance with UNI 11367, where the calculation of the mean value is between 500 Hz and 1 kHz.

3. RESULTS

Figure 2 shows the results of the reverberation time measurements performed in occupied classrooms accompanied by optimal values indication. Only 7 classrooms out of 12, indicated as classrooms with "good" acoustics, are featured by a reverberation time lower than 1 s, and only one classroom meets the standards (A_1). Figure 3 shows the C50 in the center of the room with active source in S1. Only half of the classrooms satisfy the requirement of intelligibility.

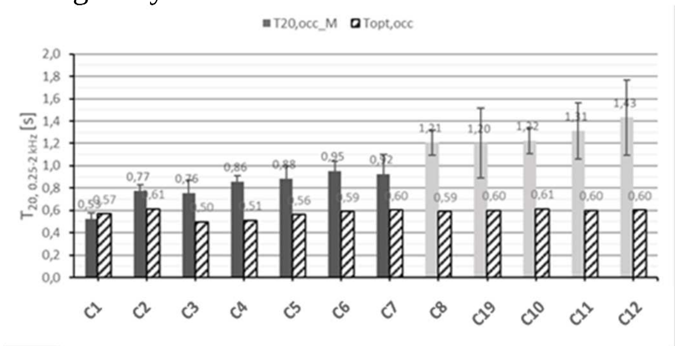

Figure 2 – Reverberation time in occupied classrooms.
The error bars indicate the standard deviation of the measurement. The solid hatched bars indicate the discrimination between classrooms with values below (darker) and above (lighter) 1 s. The dotted bars indicate the optimal values.

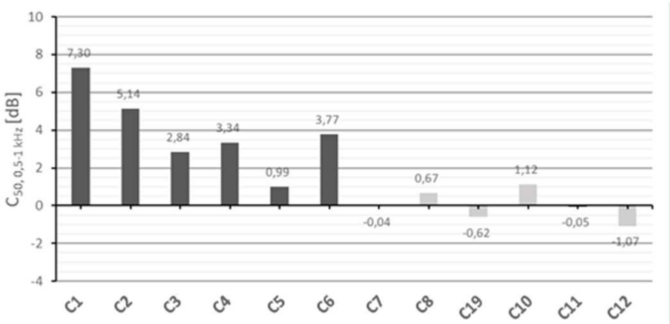

Figure 3 – Clarity C50, measured at the center of the occupied classrooms. Optimal values are greater than one.

4. CONCLUSIONS

The purpose of the present work was to provide a useful protocol for acoustics measurements in classrooms or in small environments where speech plays a key role. The protocol can be universally applied and suited for every specific situation: each classroom has its own size and configuration and it is very important that measurements are performed systematically, considering the same scheme to be repeated. This make it possible to create a database of comparable values and to do further analyses.

Half of the classrooms involved in the present study are characterized by an insufficient sound quality compared to the optimal reference values. Some of the recently renovated classrooms have a "good" acoustic quality, but none can be considered with excellent acoustics. Often, a reduced budget leads to interventions not sufficient to obtain high performances. Reverberation causes major problems, as it concerns the impairment of the clear perception of syllables over time and the amplification of the internal noise. The intelligibility is good in classrooms with good acoustics, while it is insufficient in the other classrooms.

REFERENCES

[1] Puglisi G.E., Astolfi A., Cutiva L.C.C., Carullo A., Four-day-follow-up study on the voice monitoring of primary school teachers: relationships with conversational task and classroom acoustics, J. Acoust. Soc. Am. 141(1) (2017), pp. 441-452.

[2]Shield B.M., Dockrell J.E., The effects of environmental and classroom noise on the academic attainments of primary school children. J. Acoust. Soc. Am. 123(1) (2007), 133-144.

[3] Bradley J. S., Reich R.D., Norcross S.G., On the combined effects of signal-to-noise ratio and room acoustics on speech intelligibility. J. Acoust. Soc. Am. 106(1) (1999), 1820-1828.

[4] Picard M., Bradley J. Revisiting Speech Interference in Classrooms. Audi-ology, 40(5) (2001), 221-244.