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The impact of urban noise on primary schools. Perceptive evaluation and objective assessment

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ABSTRACT

This paper aims to assess the impact of environmental noise in the vicinity of primary schools and to analyze its influence in the workplace and in student performance through perceptions and objective evaluation. The subjective evaluation consisted of the application of questionnaires to students and teachers, and the objective assessment consisted of measuring *in situ* noise levels. The survey covered nine classes located in three primary schools. Statistical Package for Social Sciences was used for data processing and to draw conclusions. Additionally, the relationship of the difference between environmental and background noise levels of each classroom and students with difficulties in hearing the teacher's voice was examined. Noise levels in front of the school, the schoolyard, and the most noise-exposed classrooms (occupied and unoccupied) were measured. Indoor noise levels were much higher than World Health Organization (WHO) recommended values: $L_{Aeq,30min}$ averaged 70.5 dB(A) in occupied classrooms, and 38.6 dB(A) in unoccupied ones. Measurements of indoor and outdoor noise suggest that noise from the outside (road, schoolyard) affects the background noise level in classrooms but in varying degrees. It was concluded that the façades most exposed to road traffic noise are subjected to values higher than 55.0 dB(A), and noise levels inside the classrooms are mainly due to the schoolyard, students, and the road traffic. The difference between background ($L_{A95,30min}$) and the equivalent noise levels ($L_{Aeq,30min}$) in occupied classrooms was 19.2 dB(A), which shows that students' activities are a significant source of classroom noise.

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1. Introduction

Urban noise is a major factor that can degrade quality of life in cities. These problems are generally worsening due to the unbalanced urban development and increasing mobility and road traffic [1–3]. Although the exposure of communities to environmental noise is a global concern, most cities are still subjected to noise levels that disturb human activity.

Many studies have already proven that noise is largely responsible for many risk factors that may impair physical and mental health in humans [4]. Temporary or permanent loss of hearing, loss of sleep, and stress and irritability are other discomforts subsequent to its exposure, as mentioned by Björkman [5] and Lercher [6]. Matheson et al. [7] concluded that exposure to aircraft and road traffic noise can have an impact on certain aspects of a child's episodic memory. The author additionally revealed that aircraft noise is associated with impairment of recognition memory, and road traffic noise is associated with improved performance on cued recall in a linear exposure-effect relationship.

The noise can interfere with the teaching and learning process. In a school environment, noise can impair the process of teaching and learning by interfering in the course of educational activities. Activities requiring concentration are more difficult to perform in noisy environments [8]. In the classroom, students and teachers develop their activities just like any worker in the workplace [9]. The impact of urban noise also affects the work environment; hence, the problem of noise has spread to schools, offices, and other places [10]. The noise in the school environment affects the teaching and learning process. This process needs good verbal communication, especially at the beginning of school life, when children have not yet developed their hearing strategies, thus impairing the understanding of certain activities in the case of not being able to hear the full statement [11]. Dockrell and Shield [12] demonstrated that children were able to discriminate between situations with varying amounts and types of noise and

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stated that children can be sensitive judges of their noise environments. To Eniz [13], children who are in the process of acquiring vocabulary are the most affected by not always understanding exactly what their teacher is saying. The problems caused by noise in children and adolescents are decentralisation, low productivity, interference with communication and learning difficulties. Connolly et al. [14] conducted an online questionnaire survey of adolescent perceptions of their school's acoustic environment and concluded that pupils with additional learning needs along with older pupils are significantly more affected by poor school acoustics. A study carried out by Ali [15] on the effects of school noise on learning achievement concluded that there is strong relationship between noise levels and the percentage of highly annoyed students; in fact, 57% of respondents said that noise obstructed their learning achievement.

The noise characteristics and the physical characteristics of the classroom are factors that can influence the students. Astolfi and Pellerey [16] showed that students were more disturbed by intermittent than constant noise. Kennedy et al. [17] developed a perception of listening ease (PLE) score for each student and demonstrated that PLE is a useful measure of student perception of the classroom-listening environment and that optimal classroom acoustical design must take into consideration "in-use" conditions as well as classroom physical characteristics.

The background noise levels in schools are due to noise sources within the classroom and from external sources. Sarantopoulos et al. [18] concluded that simultaneous measurements of indoor and outdoor noise levels in 15 school complexes suggest that noise from the outside (road and schoolyard) affects the background noise level in the classrooms. The value proposed by Berglund et al. [19] for the background noise level of 35 dB(A) in classrooms, based on the assumption that the level of sound produced by the teacher's voice is equal to 55 dB(A), for a distance of 1 m. The maximum noise level of 55 dB(A) for playgrounds is the same value reported on the outside of residential areas during the day in order to avoid annoyance. Background noise levels in unoccupied classrooms are due to noise sources within the classroom, such as ventilation system noise, noise from other areas of the school, and from external sources. A survey in seven classrooms of primary schools found that the background noise levels ranged from 35 to 45 dB(A). Other studies in primary schools recorded background noise levels between 45 dB(A) and 48 dB(A) in unoccupied classrooms, assuming no acoustic treatment. In classrooms with students, the measured activity ranged between 56 dB(A), when students were silent and 77 dB(A), when the students were engaged in noisier activities involving group work and movement around the room [20].

In Portugal the maximum noise levels in sensitive areas such as schools, are limited by the Noise Regulation [21]. Based on the land uses established by the Master Plan and Portuguese Legislation [21], the acoustic zoning map classifies land into two classes: "sensitive areas," which currently are (or likely will be) used for residences, schools, hospitals, recreation, and leisure; and "mixed areas," which include sensitive uses as well as retail shops and services, parking, etc. The law prescribes weighted average sound level standards for the entire day [Lden(A)[and for the night [Ln (A)]. Sensitive areas may not be exposed to an equivalent continuous sound level higher than 55 dB(A) during the entire day (average value over the day, evening, and night periods), and 45 dB(A) during the night; mixed areas may not be exposed to more than 65 dB(A) during the entire day and 55 dB(A) during the night (see Table 1).

The present study aims to assess the impact of environmental noise from the vicinity of schools inside the classroom in order to analyze the teaching and learning noise conditions in the classrooms through perceptions and objective evaluation. Additionally this study proposes to examine the relationship of the background noise levels of each classroom and the difficulties in hearing the teacher's voice reported by the students.

Table 1
Exposure limit values for noise in sensitive and mixed areas.

Area	Daytime-evening-night indicator	Night indicator
Sensitive	55 dB(A)	45 dB(A)
Mixed	65 dB(A)	55 dB(A)
Unrated[a]	63 dB(A)	53 dB(A)

[a] Applies to sensitive receivers located in uncategorised zones.

2. Methodology

The adopted methodology for the assessment of environmental noise in the vicinity of schools included two basic types of evaluation: perceptive and objective. Additionally, the difference between background and environmental noise levels in occupied classrooms was measured in order to evaluate the relationship with the percentage of students with difficulties in hearing the teacher's voice.

2.1. Perceptive evaluation

The subjective evaluation consisted of noise perception by students and teachers and, for that, questionnaires were developed based on the Magalhães and Silva [22]. The survey covered nine classes located in three primary schools. This survey targeted students of the third and fourth grade as well as the teachers.

Student questionnaires consisted of simple questions of closed answers, while the teacher questionnaires required the assignment of an ordinal scale value of 0, 1, 2, or 3, in response to sensibility to different noise sources, meaning "none," "a little," "some," and "a lot," respectively. For data processing, Statistical Package for Social Sciences (SPSS®) v.19.0 and Microsoft Office Excel v.12 were used. Blank answers were disregarded in the statistics. Processed data results were presented in relative (%) and absolute (n) frequencies.

The sample involved 213 students, 51.2% ($n = 108$) were males and 48.8% ($n = 103$) females, in an age range of 8–11 years old, as well as 20 teachers, 10% ($n = 2$) males and 90% ($n = 18$) females, in a 25–60 years old range.

2.2. Objective evaluation

Measurements of environmental noise were performed, as described in ISO 1996:2011 NP entitled "Description, Measurement and Assessment of Environmental Noise."

For the measurement of noise levels, a sound-level meter of accuracy class 1 was used, from CESVA, model SC310, which was checked and calibrated by the Portuguese Institute for Quality (IPQ). A tripod was used to ensure stability of the measurements.

The A mesh-frequency weighting method was used and fast mode reading was utilized to characterize the environmental noise, while the impulse mode was used to detect impulsive characteristics of the noise. The sound-level meter was programmed to gather the following noise indicators: $L_{A95,30min}$ and $L_{Aeq,30min}$. Measurements were performed on the outside and inside of each school with the school open (i.e., with the students in school activities) and with the school closed (i.e., with an empty school). All these measurements were performed on the daytime period. For the assessment of environmental noise on the outside, the number of measurement points was defined based on the playground and on the possibility of measuring both situations (school open or closed). In all measurement points, the sound level meter was

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