Research Article

Lucia Busa, Michele Goretti, Claudia Guattari*, and Paola Pulella

Extra-auditory effects of noise exposure in Italian schools: noise levels in external areas

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Abstract: Schools in urban areas are often located in areas with high traffic and noise pollution that affect the overall and sonic quality of the external spaces. Due to this, teachers and students are exposed to high noise levels, this condition could have an impact on the perceptive-cognitive and neurobehavioral aspects, determining auditory and extra-auditory effects from exposure to noise. The BRiC - ID14 project, funded by INAIL, investigates the extra-auditory effects of noise exposure on primary and secondary school teachers and students.
In this study, the assessment of sonic, acoustic and overall environment of the external area of three kindergartens, three primary schools and three secondary ones located in Rome, Florence and Perugia was carried out. The external areas were investigated and discussed by analyzing the acoustic, psychoacoustic and subjective data collected. The results obtained by the acoustic measurements campaign under non-occupied conditions were compared with the soundscape measurements outcomes, under occupied conditions. The two measurements campaign revealed that the obtained values are comparable in terms of objective and subjective responses. The differences observed in the perception of the sonic and overall environment are ascribable to different noise sources located close to the schools.

Keywords: Noise exposure; soundscape; external acoustic climate

1 Introduction

The BRiC INAIL 2019-ID 14 project involves five Italian universities in the ambitious research work on how inadequate acoustic contexts can determine extra-auditory damages. The project, which began in June 2020, mainly investigates the problems connected to school environments and extra-auditory effects observed at a physiological, neurobehavioral and perceptive-cognitive level in people who live those spaces [1, 2]. This paper shows the measurements campaign carried out on the external areas of the schools, concerning measurements and evaluations of the schools' acoustic climate, also through the soundscape approach, and the noise to which operators in the school sector are exposed in specific environments (classrooms, common areas, dining halls, gyms, external spaces and other spaces deemed significant).

In order to evaluate the acoustic quality of school environments, which are considered as possible causes of extra-auditory damages due to exposure to noise, the project provides different investigation scenarios and the assessment of operational indications for the acoustic analysis of these environments.

The sound sources that characterize school buildings are located both inside and outside them. It should be noted that the noise coming from outside is mainly due to road, rail and airport infrastructures, eventually located close to the schools. Furthermore, some external sources are linked to the students' activities in the open spaces of the school: courtyards, gyms, play areas, sports fields. In some cases, noise from construction sites and natural sounds were identified. On the other hand, internal noise sources are primarily linked to student activities inside the classrooms: they obviously have a high significant impact in terms of moving activities, such as chatter among students and noise from tables and chairs movement.

In the external areas, the prevalence of artificial sounds, audible wave or vibrations generated by artificial sources can have a strong influence on users' noise annoyance [3]. This annoyance leads to a discomfort or negative health effects on people [4, 5].

In this paper, the evaluation of sonic and overall environment of the external areas of the schools located in Rome, Florence and Perugia was analyzed and discussed. The external areas were investigated and described by analyzing the acoustic, psychoacoustic and subjective data collected.

***Corresponding Author: Claudia Guattari:** Department of Philosophy, Communication and Performing Arts, Roma TRE University, Rome, Italy; Email: claudia.guattari@uniroma3.it
Lucia Busa, Paola Pulella: Vie en.ro.se. Ingegneria, Florence, Italy
Michele Goretti: Department of Engineering, University of Perugia, Perugia, Italy

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2 Methodology

This study aims at evaluating the external acoustic conditions and analyzing the noise level to which operators in the school sector are exposed in specific environments. The measurement protocol defined within the BRiC INAIL19-ID14 project consists of acoustic measurements and questionnaires filled by both teachers and students, to verify the presence of possible negative effects due to exposure to noise, in each investigated scenario.

This paper describes the characterization of the external environment by means of traditional acoustic measurements carried out under non-occupied conditions. Moreover, the occupied conditions of the external areas were studied by means of the soundscape approach. The soundscape measurement campaign was performed in accordance with the ISO/TS12913-2:2018 [6]. There are several available protocols to gather perceptual data about how people experience the soundscapes in cities, and the most common tool is the soundwalk.

For this purpose, a soundwalk together with experimental measurement campaigns was organized in the external areas of the analyzed schools. A group of school's staff members and teachers was involved, applying the Method A (Section C.3.1of the ISO/TS 12913-2:2018) [6], while experiencing the acoustic environments under occupied conditions (morning break).

2.1 The case study

Following the project indications, the protocol was applied for the sonic and overall characterization of schools' external spaces and their acoustic evaluation. These investigations were conducted in nine schools located in Florence, Perugia, and Rome (three for each city), selected as case studies. The analyzed schools are three kindergartens, three primary schools and three secondary schools, involving teachers, staff members and students of different typologies and ages. More in general, within the school buildings, seven educational scenarios were considered: classroom (S1), laboratory (S2), auditorium (S3), gym (S4), common area (S5), dining hall (S6), external area (S7). In particular, in this study the acoustic climate of the external areas and the correlation between objective and subjective parameters were analyzed and compared.

The investigations defined in the protocol consist of acoustic measurements and soundscape analysis of the external environments of the nine schools (Figure 1).

2.2 Procedure, measurements campaign and questionnaires

In accordance with the described methodology, acoustic climate measurements were carried out in the investigated areas (S7 scenarios).

The acoustic climate was measured as the A-weighted equivalent sound pressure level, LA_{eq} in dB(A), for the whole daytime activity of the school and compared with the limit values imposed by the Acoustic Classification Plan of each Municipality, for the class to which the schools' areas belong to. Moreover, a questionnaire about the acoustic conditions was filled by teachers and students.

On the other hand, the soundwalk was performed in accordance to the ISO 12913–1:2014 [7] and ISO/DIS 12913–2:2017 [8]. The questionnaire proposed by the Method A of the ISO/TS 12913-2:2018 [6] needs to be filled out by the

Figure 1: The investigated schools' external areas

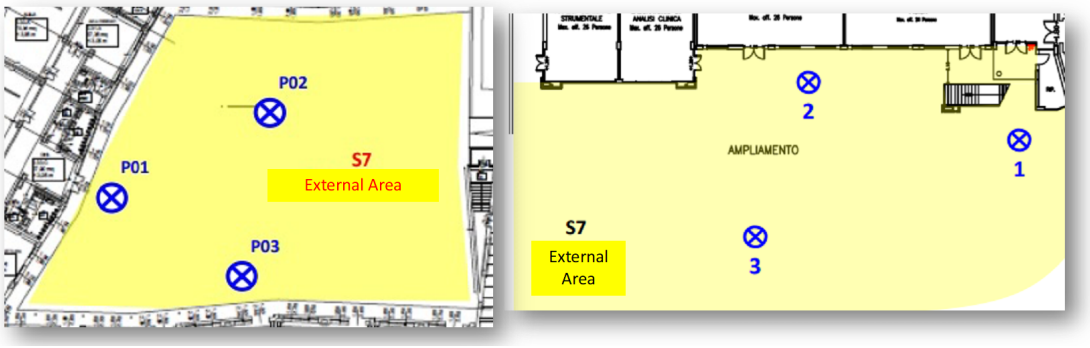

Figure 2: Examples of soundwalk locations and questionnaires

participants. Together with the questionnaire, an experimental campaign was carried out in order to combine the users' subjective response with the objective data provided by the measurements (Figure 2).

Thirty staff members and teachers voluntarily participated to the soundwalk. The participants gave informed consent, and the research was accomplished according to the ethical requirements of the Helsinki Declaration.

Throughout the survey, a specific instrument performed binaural recording. The whole session (*i.e.*, soundwalk + binaural recordings) was carried out in October 2022, for each school in each city during the morning break. In order to evaluate how the human beings, detect the acoustic environment, binaural acoustical measurements were carried out in compliance with Annex D, using a Head Acoustics device. Taking into account the binaural measurements, the recording time was a two-minute interval, which was recorded at the same time while the participants were listening to the acoustic environment and were filling the questionnaire, at each location of the soundwalk.

3 Results and discussion

The acoustic external climate was measured in each S7 scenario, for each school in each city. For the sake of brevity, the results of three of the studied schools will be presented, the primary schools in Florence and Rome and the secondary one in Perugia. These schools show the most interesting results.

For each scenario, the time slot in which the LA_{eq} sound level was highest was highlighted. The experimental results show that the limits imposed by the acoustic classification are exceeded only in the external area of the secondary school of Perugia. In fact, here a maximum value of 55.8 dB(A) was measured, where the maximum limit is equal to 50 dB(A). This is due to the proximity of the school to two significant transport infrastructures, a railway and an interstate highway.

The comparison among the sound pressure levels recorded in the S1 scenario (classroom), which refer to the occupied and unoccupied conditions, points out that the noise coming from external activities is negligible compared to the internal sound pressure levels measured during the daytime activity.

The comparison was made among the sound levels measured for the S1 scenario relating to LA_{eq} under occupied conditions, L_{amb} in a non-occupied environment and LA_{eq} in the external area. The results of the measurement campaign are shown in Table 1.

This is also confirmed by the elaboration of the questionnaire filled by teachers and students on the perception of the disturbance of noise coming from the external areas.

Table 1: Results of the acoustic measurements campaign

Scenarios	L_{aeq} [dB(A)]	Kindergarten			Primary School			Secondary School		
		Florence	Perugia	Rome	Florence	Perugia	Rome	Florence	Perugia	Rome
S1 Classroom	Occupied environment	71.2	74.8	-	71.1	68.7	70.7	63.8	68.7	-
	L_{amb} [dB(A)]	29.8	22.8	45.6	-	37.2	36.5	38.4	45.1	34.8
	External acoustic climate	52.7	45.3	47.7	<53.4	56.8	56.4	59.8	60.5	53.9

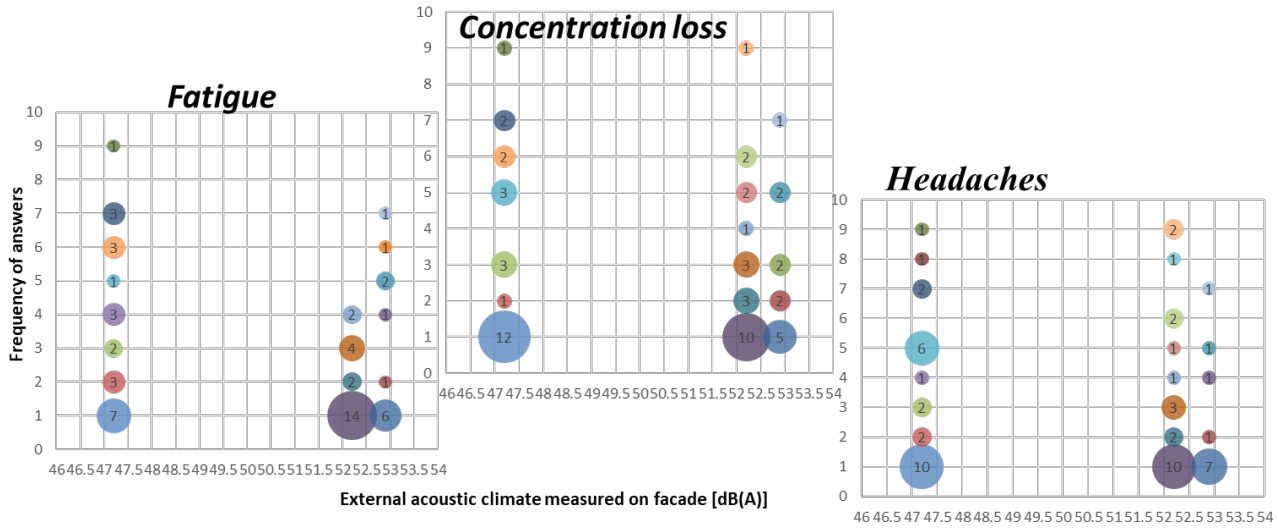

Figure 3: Relationship between the acoustic climate measured on façade and the questionnaires responses

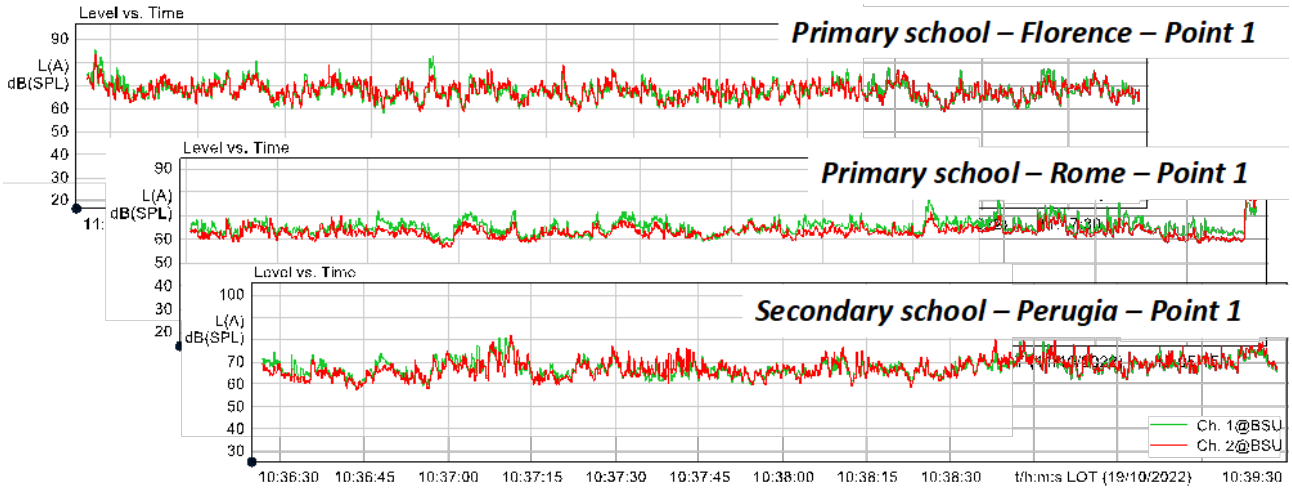

Figure 4: External sound pressure levels recorded under occupied conditions

A correlation was identified between the level measured on the facade and the perceived disturbance: about 70% of the investigated sample did not consider the noise coming from outside disturbing.

Considering the other 30%, who declared themselves disturbed, more than 65% experience relapses on fatigue and concentration loss, while around 50% experience negative effects on health (headaches) and on neuro/behavioral aspects (anger and boredom).

Starting from the investigations carried out within this project, it can be highlighted how the noise levels detected in the external areas of the selected schools, considering people aged between 6 to 18 years, are not considered to be the cause of the main extra-auditory effects related to health, neuro/behavioral and perceptual/cognitive aspects (Figure 3).

Taking into account the measurement campaign carried out by means of the soundscape approach, psychoacoustic measurements were carried out and questionnaires was filled in the schools' external areas usually used by staff members, teachers and students, in order to evaluate the acoustic environment, both under objective and subjective point of view.

Psychoacoustic measurements in binaural headphones during the soundwalk were performed and questionnaires were filled by staff members and teachers during the soundwalk.

The soundscape approach confirmed the analysis previously described in terms of sound pressure levels values recorded, as it can be seen in Figure 4.

The sound pressure level measurements shown how the LA_{eq} values recorded during the morning break are clearly higher than the corresponding values measured in an unoccupied environment, which are lower than the limit imposed by the law. Exception is done for Perugia's case study, but also in that case the recorded value under non-occupied conditions is lower than the one measured during the morning break. This is evidently due to the activities carried out in the survey area. The sound pressure level values are in accordance with the perceived loudness values.

From the analysis of the questionnaires filled in Florence and Rome, as it can be seen in Figure 5 and Figure 6 respectively, the soundscape was evaluated homogenously by the participants at the different measurement points within the same school.

The overall judgment on the acoustic environment for the different measurement points in the different schools was homogeneous, except for the secondary school of Perugia given the proximity to road and rail infrastructures

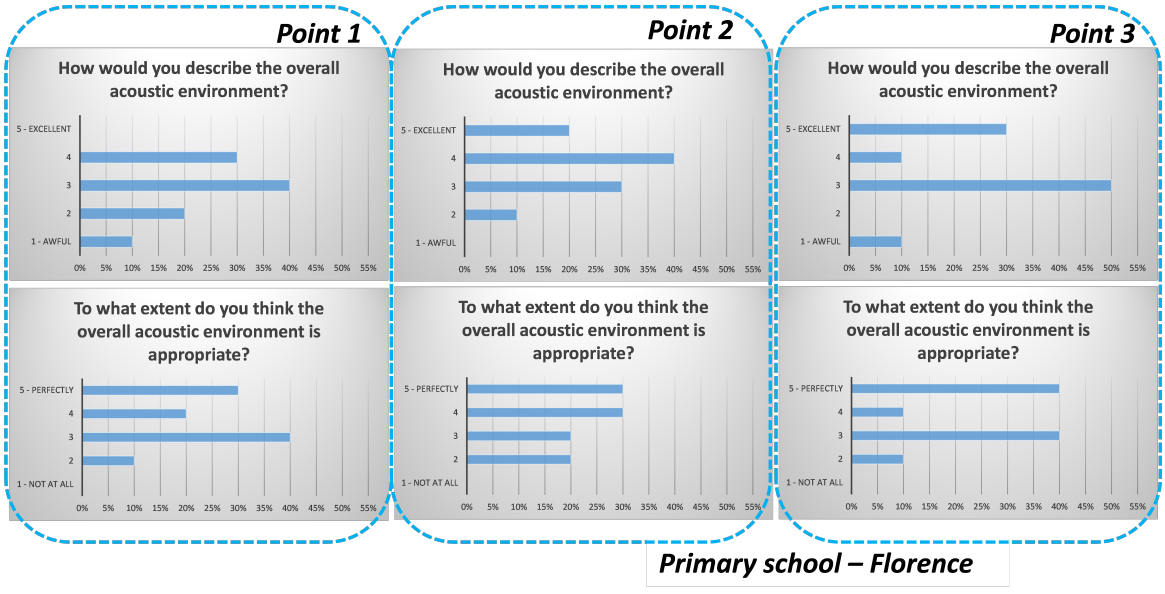

Figure 5: Subjective response at the primary school of Florence

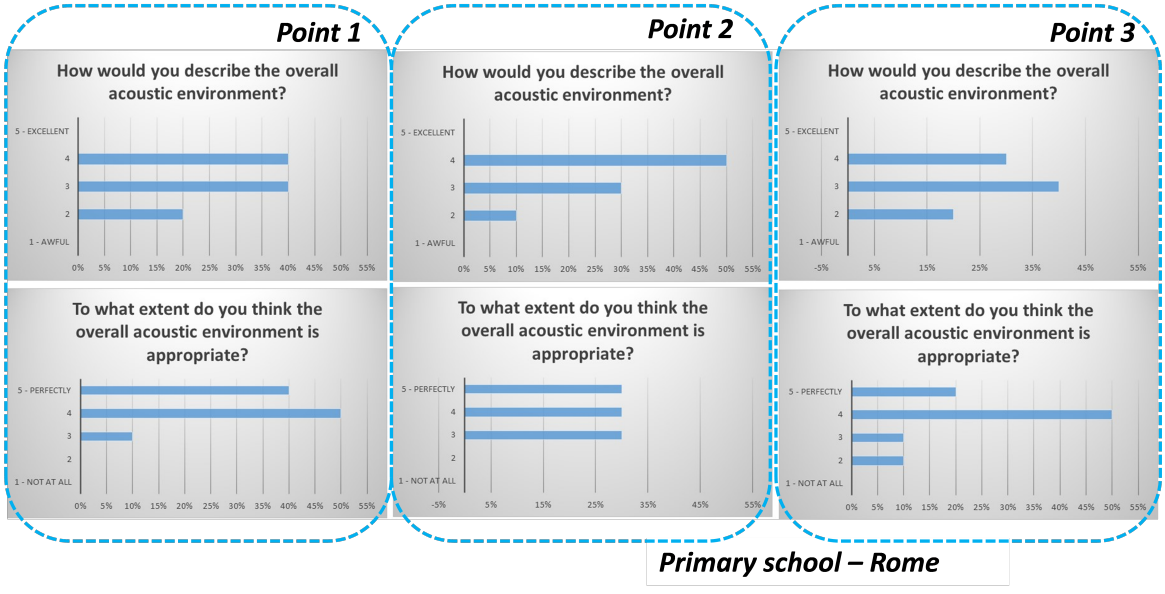

Figure 6: Subjective response at the primary school of Rome

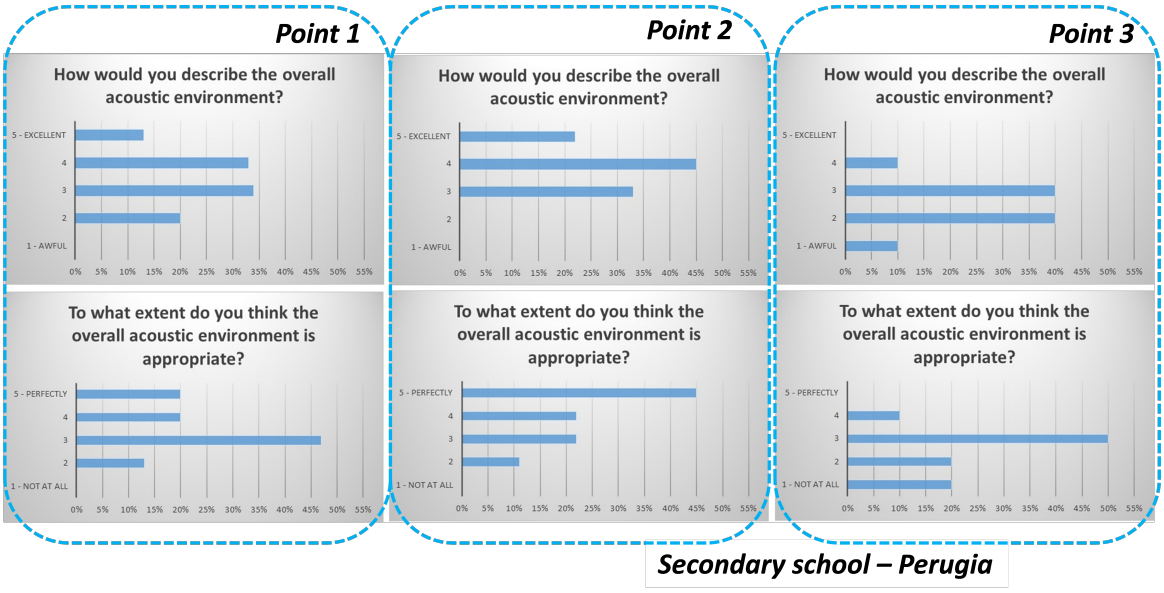

Figure 7: Subjective response at the secondary school of Perugia

(Figure 7). In this, in fact, the responses were different in function of the measurement point and its distance from the noise sources.

4 Conclusions

In this paper, the evaluation of sonic and overall environment of the external three different schools located in Rome, Florence and Perugia was carried out. The external areas were analyzed by investigating the acoustic, psychoacoustic, and subjective data collected. The results obtained by the different measurements campaigns, performed under non-occupied conditions were compared with the soundscape measurements outcomes, under occupied conditions.

The comparison among the levels measured in the S1 scenario (classroom), which refer to the different parameters under occupied and unoccupied conditions, shows how the noise coming from outside is negligible compared to the internal sound levels measured during the standard activity.

The external areas (S7) in the different case studies are generally shielded from noise coming from outside, the average sound pressure levels recorded over the whole school activity are between 45 and 55 dB(A). The lowest sound levels were detected in the external areas of kindergartens where these are always lower than 50 dB(A).

With regard to the use of external space, almost 90% of the sample interviewed declared that it was used for recreational purposes and that the noise generated do not lead to negative effects on health (headaches) and on neuro/behavioral aspects (anger and boredom).

Taking into account the judgment on the acoustic quality perceived in outdoor space, more than 70% of the sample believes that they almost never have to raise their voice to be heard by other students, regardless of the sound levels measured outdoors. This confirms the effectiveness of the 55 dB(A) limit for outdoor areas for the purpose of carrying out recreational activities.

Moreover, considering the soundscape analysis, the measurement campaign together with the subjective data show that the negative evaluation of the external area is related to the noise sources typology and not to the sound pressure levels values. In fact, the sound pressure levels recorded for each school in each measurement point are homogeneous, but the subjective responses reveal negative judgement only in the case of the Perugia's secondary school, where the noise sources are road and rail infrastructures. In all other cases, even if the sound pressure levels are quite high, the soundscape is considered appropriate (recreational activities), and the judgements are positive.

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