CORRELATION BETWEEN PERCEIVED AND MEASURED NOISE, WITHIN THE GIOCONDA PROJECT

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The GIOCONDA Project provides an innovative procedure to effectively support the young people involvement in the decision-making processes on environment and health. The procedure is based on the combined evaluation of air and noise pollution measurement results with the risk perception and willingness-to-pay (WTP). A measurement campaign has been developed, while the students reported their risk perception on noise in a questionnaire. The combination of these data could allow the understanding of the gap between the perceived and the objective pollution. Two schools (primary and secondary schools) in four cities along Italy have been involved in the project. Cities have been chosen to represent different situation of noise pollution and environmental contexts. For each school, three classrooms have took part in the project. The noise measurement campaigns have been performed to characterize the students' noise exposure in the classrooms, in function of six acoustic parameters and a global noise score, created on purpose to this project.

1. Introduction

The GIOCONDA project (i GIOvani CONtano nelle Decisioni su Ambiente e salute, Young voices count in decisions on env&health) [1], began in June 2014 and it will end in November 2016, has been funded within LIFE+ Environment Policy and Governance (LIFE13 ENV/IT/000225). The project aims to provide an innovative methodology to the authorities for supporting the environment and health policies by involving the young people in the decision-making processes. The project suggests a web platform able to relate air and noise pollution data in the schools with the students' pollution awareness. GIOCONDA aims to enhance the awareness of students, teachers and local administrations on the noise issues in schools, presenting suitable tools to improve the public participative processes. In the first period, eight Italian schools placed in four cities, joined the project. The project has the purpose of filling the gap between young people and public administrations about environment and health issues, considering that young people will lead the environment and the health of tomorrow by means of their perception and behaviour. This is a chance to understand the gap between subjective perception and real pollution.

The GIOCONDA Project provides an innovative procedure to effectively support the young people involvement in the decision-making processes on environment and health. The procedure is based on the combined evaluation of air and noise pollution measurement results with the risk perception and willingness-to-pay (WTP)[2] related to environmental health issues. Since the project involves cities with different kind of pollution sources, a holistic approach [3] has been applied. Alongside the measurement campaigns, the students reported their risk perception on noise, air, waste and water pollution and also provide their WTP related to each issue. The combination of these data could allow the understanding of the gap between the perceived and the objective pollution. Some previous studies already investigated this gap [4], [5], [6], [7], [8], but this project aims to offer a further step in communicating the results to the surveyed students and to increase their awareness about the negative effect of a noisy environment on the learning process. Finally, an online platform will be developed in order to facilitate the application of environmental and health risk governance and policies. The platform will include tools for the decision makers that may be useful to estimate the costs and benefits of policies regarding the air pollution and/or the noise exposure, while other tools will enable schools to measure the students' perception of their surrounding environment. As a further result, in the second year of implementation of the project, it will be possible for students to discuss and use the platform in order to suggest solutions to the public administrations.

The GIOCONDA project involved 8 schools of different type (primary and secondary school), two for each location: Naples (a principal city of Campania Region - South Italy characterize by urban and industrial areas), Ravenna (a city of Emilia-Romagna Region – North Italy characterize by urban and industrial areas), Taranto (a big city of Puglia Region – South Italy characterized by urban and industrial areas) and Valdarno (an area of Tuscany Region characterized by urban and rural areas). The sample included 28 classes for a total of 521 students.

This paper presents the correlation between perceived and measured noise. Perceived noise has been carried out through questionnaires given to the students.

Simultaneously, the noise measurement campaigns have been performed to characterize the students' noise exposure in the classrooms participant to the project. The monitoring results are useful to be compared with the questionnaires results.

2. Method

2.1 Measurements of Risk Perception Index

Data collection was performed using a self-administered questionnaire (with the teacher support, if necessary) completed in the classroom setting. The questions, arranged in different sections, were designed to investigate the level of awareness on environmental issues, the perception of risk related to environment and health, and the willingness-to-pay.

2.1.1 Noise related questions

Respondents were asked to express their degree of concern on a series of questions. The following noise-related questions were used:

Table 1: questions relating to noise.

a	"Do you think your school is noisy?"
b	"How annoying is the noise you usually hear when you're at school?"
c	"The annoying noise in the area around your school is causing you any problem?"
c1	I do not hear people speaking in the room
c2	The noises distract me
d	"How often do you notice noise?"

- Questions a, b, d were on a Likert-type format (1-5) with the following options:
  - Questions a-b, “not at all, a little, somewhat, much, very much”;
  - Question d, “never, seldom, sometimes, often, always”;
- Questions c1, c2 were on dichotomous answer (yes/no).

2.1.2 Individual risk perception index

Questions reported above were used to estimate the individual Risk Perception Index RPI [9].

The RPI is calculated as a weighted average of absolute frequencies of each choice:

$$RPI = \frac{\sum_i^k n_i \pi_i}{N \cdot (k-1)} \quad (1)$$

where: ni represents the absolute frequency of the ith mode (e.g. not at all, a little, somewhat, much, very much); πi represents the weight assigned to the ith mode (e.g. 1 = not at all, 2 = a little, 3 = somewhat, 4 = much, 5 = very much); N represents the total number of observations (i.e. the total number of respondents); k represents the number of points (in this case =5) in the Likert scale.

The values of the dichotomous variables were treated as two points on the Likert scale, so the value 0 (“no”) was turned into 1 (“not at all”) and the value 1 (“yes”) into 3 (“somewhat”).

The RPI value ranges between zero and one: the more the value is close to one, the greater the risk perception.

For each class the median of RPI was calculated (MRPI).

2.2 Measurements of noise data

To acoustically evaluate any classroom with single specific indicators and with a global indicator representing the judgment of the overall noise situation, the following main steps were followed:

1. setting a list of significant acoustic parameters to investigate;
2. establishing a score range for each parameter;
3. establishing a Global Noise Score GNS to be assigned to the classroom, with a related score range;
4. carrying out the measurement campaigns;
5. analysing the data and providing the results;

The quality and intelligibility of speech in a classroom mainly depends on both the noise level and the amount of reflected sound, which increases the noise level and masks the speech itself. Thus, the noise and the reverberation outline the acoustical environment of a classroom. Concerning the noise, outside the school it is mainly due to transport infrastructures and industrial areas, whilst inside the classroom it is also related to other sources, such as building services (heating, lighting, ventilation systems), teaching aids (overhead projector, computers) or the ongoing lesson. Reverberation describes the amount of reflected sound and it depends on the room volume and the acoustic characteristics of all the surfaces inside the room, as walls, ceiling, floor, desks and whiteboards.

Bearing in mind these considerations, a common set of six parameters, defined in accordance with international standards, were proposed:

- the LDAY for investigating the exposure to external sources, calculated from:

1. external noise monitoring (LDAY-Ext);
2. internal short-term measurements (LDAY-Int);

- the following four parameters for investigating the building acoustics characteristics:

3. façade insulation: D2m,nT,w ([10], [11]);
4. wall insulation: R’w ([12], [13]);
5. reverberation time: RT ([14]);
6. speech intelligibility index: STI ([15]).

Each parameter has been categorized in five classes: the higher one (score 5) has been chosen to fulfil the Italian limit values ([16], [17], [18], [19]), which are very hard to be observed, the others have been set according to the scientific literature or to the international optimal values ([20], [21], [22], [23], [24]). The score ranges proposed are reported in Table 1.

Table 2. Score ranges for each parameter.

Score	**Evaluation**	$L_{DAY-Ext}$ [dB(A)]	$L_{DAY-Int}$ [dB(A)]	$D_{2m,nT,w}$ [dB]	R'_w [dB]	**RT** [s]	**STI**
5	Very Good	< 50.0	< 45.0	> 48.0	> 50.0	< 0.80	0.75 - 1.00
4	Good	50.0 - 52.5	45.0 – 47.5	48.0 - 45.1	50.0 - 47.1	0.81 - 1.00	0.60 - 0.75
3	Sufficient	52.5 - 55.0	47.5 – 50.0	45.0 - 42.1	47.0 - 44.1	1.01 - 1.20	0.45 - 0.60
2	Poor	55.0 - 57.5	50.0 - 52.5	42.0 - 39.0	44.0 - 41.0	1.21 - 1.40	0.30 - 0.45
1	Very Poor	> 57.5	> 52.5	< 39.0	< 41.0	> 1.40	< 0.30

A qualitative judgment is assigned to each class in addition to the numerical score in order to enhance the students' understanding.

All the scores can be summed up to obtain the Global Noise Score of each classroom, reported in Table 6.

Table 3. Evaluation classes: scores and related performance.

Evaluation classes	
Score	**Acoustic performance**
26 - 30	Very good
21 - 25	Good
16 - 20	Sufficient
11 - 15	Poor
6 - 10	Very Poor

The total values range from 6, corresponding to the simultaneous minimum score for all the parameters, to 30 when each parameter has the maximum score.

A single indicator could allow the students to compare their classroom or school with other ones. Moreover, the simple metrics is easily understandable even for young people: the highest is the Global Noise Score GNS, the best is the environment of the classroom.

For each classroom, the GNS is obtained summing up the score of all parameters. So, the best is the acoustic situation in the classroom, the highest is the GNS, ranging from 6 to 30.

2.3 Statistical method

For a validation of RPI, a Risk Perception Index was also calculated with a Structural Equation Model (RPI-SEM) [25], using the same set of variables used for RPI.

A Shapiro-Wilk normality test was applied to determine whether MRPI and Noise measured data were normally distributed.

The distributions of MRPI and Noise data by mean, standard deviation, 25th percentile, median, 75th percentile, 95th percentile, minimum and maximum were described.

The correlation between MRPI and Noise measured data was performed by non parametric Spearman coefficient [26].

All analysis were performed by STATA v.13love .

3. Results

The Goodness of Fit of RPI-SEM is very good (Standardized root mean squared residual – RMSE<0.10). The correlation between RPI and RPI-SEM is very high (rho=0.90). Therefore, only the results on RPI were presented.

The normality test shows that all indexes for measured noise are not normally distributed ($p<0.05$), thus a non parametric correlation test is needed. The description of a MRPI distribution and the questions used to produce it are in Table 1

Table 4: Perception of risk index–Descriptive of the distribution of "yes" answer (%) of averages of classes.

Index ***Answer***	**Average**	**Standard deviation**	**p25**	**p50**	**p75**	**p95**	**min**	**max**
MRPI ***(range 0-1)***	0.60	0.09	0.55	0.58	0.65	0.80	0.40	0.80
a ***(range 1-5)***	2.88	0.45	2.50	2.88	3.18	3.45	1.94	3.92
b ***(range 1-5)***	2.70	0.57	2.51	2.64	2.99	3.82	1.48	4.00
d ***(range 1-5)***	3.13	0.43	2.90	3.07	3.37	3.91	2.32	4.14
c1° ***(%)***	15	14	5	10	26	43	0	45
c2° ***(%)***	47	16	3.4	46	63	69	16	70

The average MRPI ranges between 0.40 and 0.80, with the highest values measured in Taranto and Napoli. The percentage of students that declare to lose attention due to noise is only the 15%.

Table 5. Noise measured index – Descriptive of the distribution of averages of classes.

Index	**Average**	**Standard deviation**	**p25**	**p50**	**p75**	**p95**	**min**	**max**
GNS	12.07	3.38	10.00	11.00	13.00	20.00	7.00	21.00
Leq_ext	60.26	8.27	54.00	61.40	64.40	71.00	37.20	73.50
Leq_int	47.39	10.62	37.90	48.45	56.70	60.10	23.10	62.60
D2m	27.33	5.65	24.00	28.00	31.00	35.00	15.00	43.00
R	38.95	8.66	31.00	42.00	44.00	49.00	21.00	49.00
RT	1.91	0.50	1.58	1.92	2.36	2.84	0.88	2.88
STI	0.51	0.06	0.48	0.49	0.53	0.66	0.40	0.68

The graph in figure 1 presents a decreasing of the risk perception (MRPI) with the increasing of the acoustic quality in the classroom, meaning that for higher GNS (i.e. lower background noise and lower reverberation time) the noise and annoyance perceived are lower.

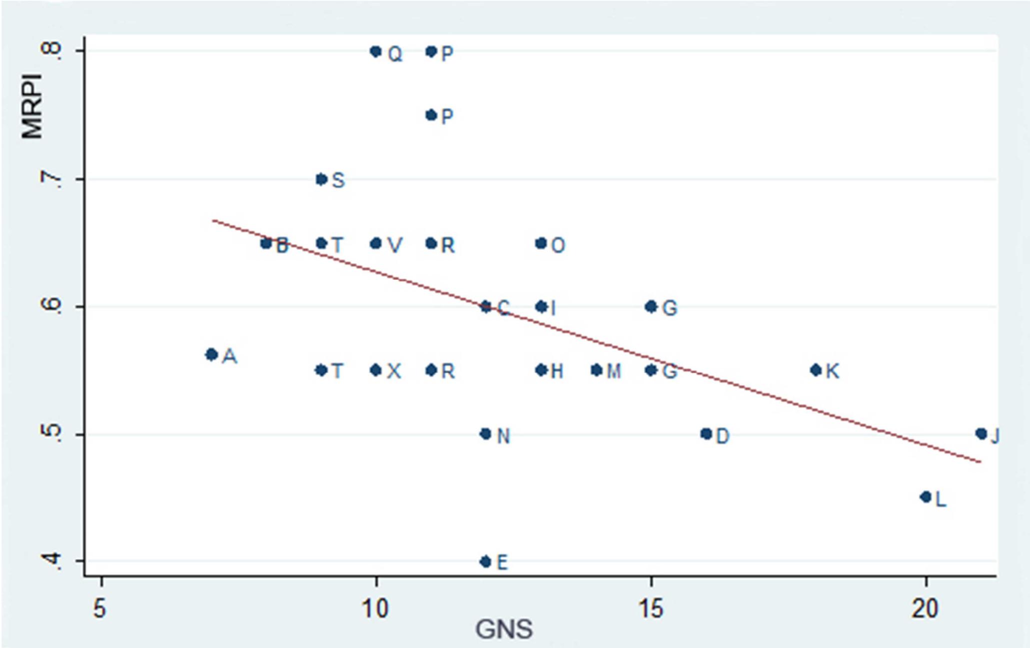

Figure 1: Median Risk Perception Index MRPI vs Global Noise Score GNS, for all the classes with measured noise. A value has been assigned to the classes with no measured noise according to a criterion of similarity and position with other classes.

In this work, in the correlation between perceived noise and measured noise, we have considered these combinations between the correlation factor rho and the p value:

- Rho > 0.5 and p < 0.05, very good correlation (deep yellow in Table 4),
- Rho < 0.5 and p < 0.05,good correlation (soft yellow in Table 4),
- Rho < 0.5 and 0.05 < p < 0.1, borderline (orange in Table 4),

Table 6: Correlation between perceived noise and measured one. Each cell contains the correlation factor (rho) and the p value. In yellow are highlighted the good correlation.

Index	MRPI	a	b	c1	c2	d
GNS	**-0.572 0.0015**	-0.425 0.0241	-0.4045 0.0327	-0.292 0.1311	-0.2098 0.2838	-0.4276 0.0232
Leq_ext	0.6113 0.0005	0.4507 0.0161	0.6051 0.0006	0.3357 0.0807	0.1446 0.4628	0.5883 0.001
Leq_int	0.6051 0.0006	0.5298 0.0037	0.437 0.02	0.3723 0.0511	0.0657 0.7399	0.3731 0.0505
D2m	0.0912 0.6443	0.0432 0.8274	0.2555 0.1895	0.0276 0.8891	0.0554 0.7796	0.1491 0.4488
R	0.1715 0,3829	0,2542 0,1918	0,1513 0,4422	-0,0338 0,8644	-0,1674 0,3945	0,1108 0,5745
RT	0.5122 0.0053	0.4031 0.0334	0.4201 0.026	0.3018 0.1186	0.0568 0.7741	0.465 0.0127
STI	-0.3303 0.086	-0.1465 0.4568	-0.228 0.2423	-0.2759 0.1553	-0.0882 0.6552	-0.3651 0.0561

Median Risk Perception Index (representing the global perception) and Global Noise Score (representing total noise situation) have a very good reverse correlation (correlation coefficient = -0.572 with 0,0015 significance statistical). The correlation is reverse because where is a better noise control, risk perception decrements.

General noise in examined schools (answer to question a "do you think your school is noisy") is perceived both inside the school and outside the school; Leq_ext outside is probably associated with noise at the entrance and at leaving the school. There is good correlated with global indicator Global Noise Score too. It is not influenced by façade insulation or speech transmission index.

Annoying (answer to questions b) is very good correlated with Leq_ext and good correlated with GNS, Leq_int, RT.

The perception of the risk is mainly associated with questions c1 and c2. They are correlate only with noise levels Leq_int and Leq_ext.

Question d "How often do you notice noise?" is related to all noise indicators, except the indicators due to structural characteristics of the classroom.

4. Conclusions

The obtained data, on the whole, show that there is a good correlation between perceived noise and measured noise in the classrooms involved in the GIOCONDA project.

GNS, the General Noise Score obtained summing the six acoustic parameters is a good indicator of the acoustic situation in a classroom, because is very good correlated with the global index Median Risk Perception and is good correlated with almost all the questions in the questionnaire. So the global noise situation in a classroom is very good correlated with the global perception that students have in their classroom and GNS is representative of the perceived acoustic situation.

Leq,est and Leq,int are good correlated with the answers to the questions about noise perception, except in the correlation with answer to question c1 "I do not hear people speaking in the room", which presents a low statistical significance. There is no correlation between Leq,est and Leq,int with the distraction due to the noise (question c2), because distraction comes especially from single events and less from background noise. With increasing Leq, the perception of risk increases, as expected.

The façade insulation D2m and the wall insulation R are uncorrelated with the noise perception, because they depend directly only on structural characteristics and not on noise level. It's easier for the students link sound level received to external sources then poor insulation of the building.

The RT is significantly directly correlated with MRPI and with almost all the answers to the questions, but not with c1 as expected, probably because students ascribe noise problems only to noise coming from outside instead to architectural characteristics of the room.

In the same way, STI is related to classroom shape and to the wall treatment, but there is not significant correlation with noise perception.

Complementary results of Gioconda LIFE+ project are presented in two papers submitted to ICSV23, where the whole process of learning and participation is described, and the specific role and importance of noise as an environmental stressor (Cori L. et al, PARTICIPATION THROUGH KNOWLEDGE SHARING AND TRANSFER: NOISE MONITORING & NOISE RISK PERCEPTION and Manzoli F. et al. PARTICIPATION THROUGH KNOWLEDGE SHARING AND TRANSFER: STUDENTS PARTICIPATION AND NOISE RISK PERCEPTION). Future developments of the research include a further analysis of questionnaires associated with environmental monitoring, increasing the number of schools and students involved in the project, so with a more numerous statistical sample, it is possible to add the correlations (with age, gender, area, etc.). Risk perception and willingness to pay will be systematically associated with noise and air pollution, taking into account the circulation of information at local level and the different socio-economic conditions.

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