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Well-being and noise annoyance outcomes from first graders and relationships with classroom acoustics

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ABSTRACT

The question on the extent to which environmental noise exposure and excessive reverberation affect well-being of children at school is still largely unexplored. Younger children of kindergarten and primary school can suffer more than older pupils of well-being and related mental health issues. Well-being measures are focused on self-esteem, emotional health and resilience, quality of the relationships with friends and family, satisfaction of school, life satisfaction. Noise exposure to traffic noise was demonstrated to be associated with mental health and behavioral problems in children, but nothing has been found until now that relates noise and excessive reverberation at school with well-being and mental health issues, despite the bad acoustic conditions that characterize classrooms in most of Europe. In this study well-being and noise annoyance from different noise sources were investigated with a subjective survey based on validated questionnaires. Twenty first-grade classes of primary schools located in Turin (Italy) participated in the study. Over 367 answered the questionnaire. Classrooms were characterized by different reverberation times and noise exposure. The happiness scale allowed to explore differences between happy and unhappy children. Relationships with good and bad classroom acoustics have also been investigated.

Keywords: School well-being, Noise disturbance, Classroom acoustics

1. INTRODUCTION

The World Health Organization (WHO) states that the school environment is a vehicle for health promotion. Focusing on the effects of the acoustic environment at school, it recognizes that high levels of noise can degrade the socio-emotional development of students as well as they can generate physical disturbs such as discomfort and headaches. Yet, negative consequences of a poor acoustic environment are particularly strong for those children with learning difficulties who are typically included in regular classes [1]. Unfavorable acoustic environments in classrooms, in fact, determine challenging environments for children, who are more sensitive than adults or older peers to noise and reverberation when performing tasks that involve listening comprehension and non-auditory features such as short-term memory, reading and writing [2]. As results, bad acoustics determines lower speech intelligibility scores, mostly for first graders [3,4], degradation of the accuracy in identifying and producing newly learned words [5], reduced reading speed of second graders [6] and lower scores in the standardized tests of literacy, mathematics, and science for pupils aged 7-11 years [7].

As abovementioned, many studies are available in literature on the relationship between classroom acoustics and teaching and learning process, even at the lowest grades of education. Conversely, a main lack in the available literature is related to the little number of studies has deepened the extent to which classroom acoustics, particularly poor acoustics, and the perception of disturbance due to noise affect the self-reported well-being of young aged children at school. Epstein & McPortland [8] and Tobia et al. [9] reported that the well-being of primary school pupils is positively influenced by learning skills, which in turn are negatively influenced by bad acoustics [6].

When noise distractors are present in a classroom, pupils' ability to understand can be degraded and the subjective perception of the sound environment can be different from a listener to another. Through the administration of questionnaires towards primary school children, Shield & Dockrell [10] reported

that pupils were annoyed more as the external noise level increased, then resulting in a reduced ability to hear the teacher speaking inside the classroom. To corroborate and go further to this result, Astolfi & Pellerey [11] proved that greater noise annoyance was observed across students when a noise source was internal in the classroom, i.e. other students talking in the classroom. Recently, Brännström et al. [12] investigated on the students' personal ratings of perceived noise in order to improve the classrooms' design, finding a strong direct relationship between noise annoyance and verbal processing demand. Thus, it is evident that the learning process is affected by the sound environment. However, the subjective perception of it can bring to light other aspects and comorbidities that go beyond the students' performance at school. In fact, the perceived well-being at school plays a crucial role that still needs insights, particularly at the earlier stages of education.

Going beyond the available knowledge is therefore necessary. Most of the previous studies on well-being for children aged less than 11 years are instead based on questionnaires administrated to parents or filled in by parents or children at home, and to the Authors' knowledge, only few works are available so far in literature that carried out well-being and noise disturbance surveys with first graders at school. This work is a pilot study that has the main aim of contributing to the knowledge related to the perception of well-being and noise disturbance at school. A questionnaire was properly designed at this work's aim, being based on Dockrell & Shield [10], Astolfi & Pellerey [11] and Sabri et al. [13]. The subjective impressions were analyzed in relationship to classroom acoustic features, particularly to reverberation time that has been used to discriminate classrooms into "good" or "bad" acoustics.

2. METHODOLOGY

2.1 Participants (subjects, schools and classes)

A total number of 367 pupils with parental consent from 20 first-grade classrooms belonging to 10 primary schools in Turin took part in the study. Twenty-seven children were excluded from the complete dataset due to cognitive or hearing deficits, or due to the incorrect completion of the questionnaires. Pupils (55% male, 45% female) were aged 6 years (62%), 7 years (37%) and 8 years (1%). The 77% of them was Italian mothertongue, whereas the other 23% reported to speak another primary language in their family context (i.e. Romanian, Moroccan, English, German, Spanish, Albanian, Egyptian). Numerosity and demographic information are shown in Figure 1.

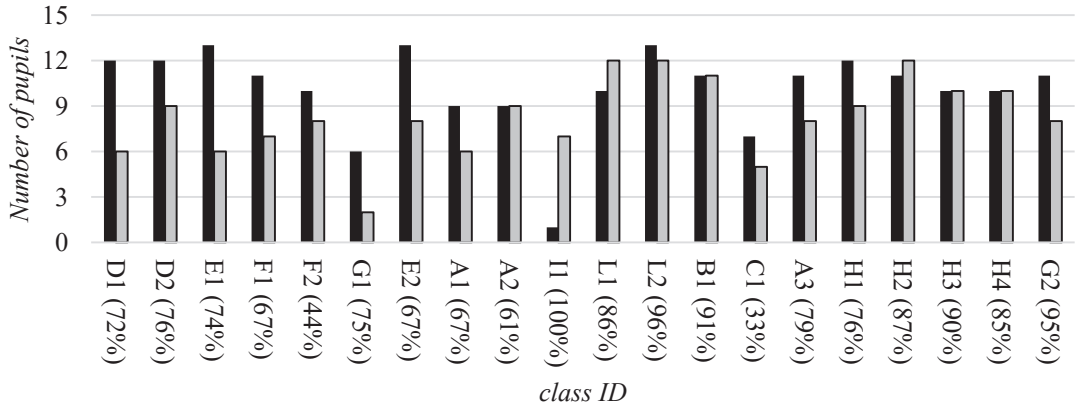

Figure 1 – Male and female students per each classroom (black and grey, respectively), and percentage of Italian mothertongue subjects, class-by-class in brackets.

As far as the involved schools and classes is concerned, school buildings presented significant differences in terms of urban location, period of construction and architectural features. They were all located in the city area of Torino (northern Italy), presenting different characteristics because of their proximity to parks or to trafficked streets, and because of the internal geometry of classrooms with volumes that varied between 120 m^3 and 290 m^3.

2.2 Classrooms acoustic parameters

Acoustic measurements were performed in the last two months of the school year. Measurements

were carried out under occupied conditions, with children inside that were on average 18 across all classes. The adopted protocol regarded the acquisition of acoustic parameters that are useful to characterize the classroom's response to easy listening. Particularly useful for the aims of the present work, the acoustic parameters of reverberation time and noise level during a silent activity in the room were acquired, and their measurement procedures are hereby detailed.

Reverberation time (T20, s) was measured according to ISO 3382-2 [14]. Room impulse responses were acquired from three repeated 3 s exponential sine sweep signals, which were emitted by a TalkBox (by NTi Audio, Schaan, Liechtenstein) and recorded by a calibrated class-1 sound level meter (SLM, model XL2 by NTi Audio, Schaan, Liechtenstein) in several measurement points inside of each classroom when occupied. Frequency averages were calculated according to DIN 18041 [15] in the range 0.25-2 kHz.

Background noise level (L_N, dBA) was considered in terms of indoor A-weighted equivalent sound pressure level (L_{Aeq}). Repeated measurements were performed based on 3 min acquisitions [16]. For this measure, the SLM was located in two or three positions in each classroom. Noise measurements were carried out with children in silence, $L_{N,sil}$. According to Shield & Dockrell [7] and BB93 [17], $L_{N,sil}$ recommended value must be less than or equal to 35 dBA.

2.3 Questionnaires

The subjective impression of well-being and noise disturbance was evaluated with children in their own classes by means of two separate questionnaires. Each survey was given to the pupils and a trained researcher, together with the teacher, assisted the compilation after each question was read aloud by a child in turn who was then asked to explain its meaning. In such a way, if it was unclear or not understood by all the classmates, an intervention by the teacher was required in order to clarify the question. In both questionnaires, items were adapted for the age of the involved children (i.e. 6 years), considering their readability, comprehension and ease of administration. Using a back-to-back translation, an Italian version of the questionnaires was obtained translating the questionnaire developed by Sabri et al. [13], suitable for young people with special educational needs, to assess perceived well-being assessment, while the questionnaire on noise disturbance was adapted on the base of the work by Dockrell & Shield [10] and by Astolfi & Pellerey [11]. Questionnaires were filled in during sessions of about 40 min during one day in May 2017 and May 2018.

Well-being questionnaire

The well-being questionnaire started with an introductory section that consists in five items on socio-demographic information such as age, gender, number of people living at home, the quietest place known by the individual, primary language spoken in family. Finally, the last item of the section and the questionnaire is an open question where the child is asked to report an opinion about the feelings of their school sound environment. Then the questionnaire presents five sections: (1) self-esteem (questions Q1_WB, Q2_WB, Q3_WB); (2) emotional health (questions Q4_WB, Q5_WB, Q6_WB); (3) relationship at home and with friends (questions Q7_WB, Q8_WB, Q9_WB); (4) enjoyment of school (questions Q10_WB, Q11_WB, Q12_WB); (5) scale of happiness (question Q13_WB). Sections 1 to 4 consist in three questions each, where a three-point ordinal scale allows to choose the accordance among the options (a) yes, (b) not sure or (c) no, where (a) corresponds to a positive feeling and (c) to a negative feeling. For section 5 the evaluation scale consists in a 11-point scale, where pupils had to put a cross on the number of an illustrated stair corresponding to their perceived level of happiness where 0 corresponded to be very unhappy and 10 to be very happy. A visual feedback with sketches and emoticons helped in the compilation of the questionnaire.

Noise questionnaire

The noise questionnaire contained three sections: (1) perceived disturbance of specific noise sources (traffic, car sirens, internal noise and natural noise, respectively; questions Q1_N, Q2_N, Q3_N, Q4_N), (2) perceived intensity and disturbance of noise during school activities performed either in silence (questions Q5_N, Q6_N) or in group (questions Q7_N, Q8_N), (3) perceived voice quality under two situations, that is, while a classmate asks a question or while the teacher explains (questions Q9_N, Q10_N). The described sections were associated with three-point ordinal scales of evaluation, in which the judging items typically varied from the less (1) to the most (3) intense/disturbing response on noise source or good (1) to bad (3) voice quality. As in the well-being questionnaire, figures and emoticons were used to make it easier to identify the type of noise being

investigated and a symbology that facilitated the indication of the perceived disturbance. Finally, the last item of the questionnaire consisted in an open question where the child was asked to optionally add comments.

2.4 Statistical methods

The statistical analysis was carried out with SPSS (IBM Statistics 20, IBM, Armonk, NY, USA). Outliers in the sample were identified applying two methodologies, namely one referring to the well-being answers and the other to the noise answers. As far as the former is concerned, pupils were grouped through a 2-means cluster analysis based on their answer to the happiness question "rate your actual happiness" (i.e. unhappy children for answers from 0 to 6, happy children for answers from 7 to 10). Then, a logistic regression has been carried out considering the membership in the group as the response variable and the other well-being answers as explicative variables, and the Cook's distance, for every pupil has been obtained. All the pupils with a Cook's distance higher than 0.15 have been recognized as outliers. As far as the noise answers is concerned, outliers have been recognized for each class, by the corresponding box-plots related to the means of all the given answers.

The significance of the differences between happy and unhappy children in good and bad classroom acoustics, related to several factors concerning well-being and noise, as well as the differences between males and females, was assessed with the Mann-Whitney U Test (MWU), a test that is used for two groups of independent observations. The relationships between the class average well-being and noise disturbance scores and the acoustical parameters, were investigated through the non-parametric and non-linear correlation analysis.

3. RESULTS

A preliminary analysis on the acoustic parameters measured in each classroom was performed and is hereby presented. Then, to assess a relationship between subjective impressions based on the delivered surveys, the analyses adopted to identify outliers led to a final sample of 326 questionnaires to be used. A furtherly reduced sample of 296 students, corresponding to the happy children only (i.e. those who answered in the range 7-10 to the happiness question), were then used for the correlation between the subjective and classes and schools' characteristics. Unhappy children have been removed from this analysis in order to have a more homogeneous sample.

3.1 Reverberation time and noise level in classrooms

Figure 2 shows the measured reverberation times class-by-class. A threshold of 0.8 s was adopted to discriminate between good and bad acoustics, according to a number of recent studies that consider this value as optimal for both the speaking and the listening tasks [18-22]. Therefore, 12 classes out of 20 resulted to be clustered as "bad acoustics", and 8 classes as "good acoustics".

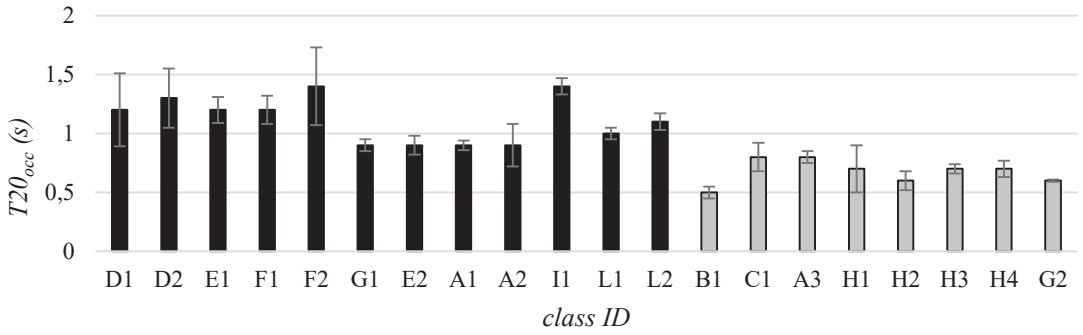

Figure 2 – Reverberation time in occupied condition ($T20_{occ}$) class-by-class. Black and grey bins correspond to classes clustered as bad and good acoustics, respectively. Error bars represent $T20_{occ}$ standard deviations.

Similarly, Figure 3 reports the background noise levels measured class-by-class when children were asked to be silent. In such a way it has been possible to capture the actual noisiness of all the classrooms, which maintained their belonging to the bad or good acoustics cluster based on the reverberation time criterion.

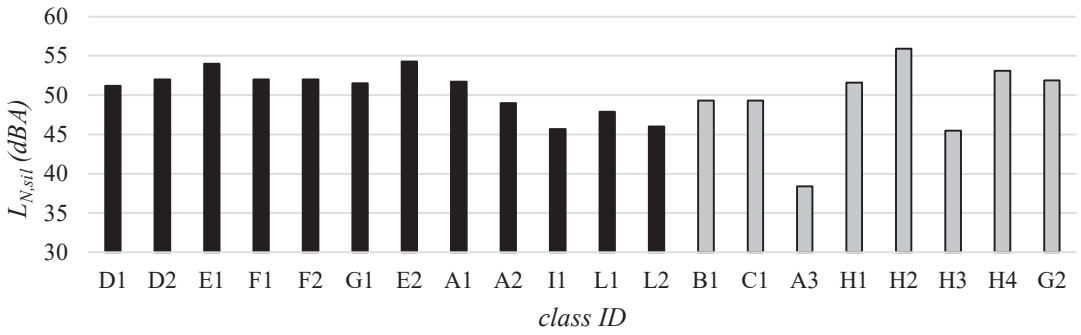

Figure 3 – Noise level measured while children were in silence ($L_{N,sil}$) class-by-class. Black and grey bins correspond to classes clustered as bad and good acoustics, respectively.

3.2 Perception of well-being and noise disturbance for males and females

A preliminary analysis has been performed that conceived the effect of gender on the subjective perception of well-being and noise disturbance. Overall, no statistically significant differences were found for all the inquired noise disturbance aspects between males and females. With respect to the well-being perception, the only two aspects related to the emotional health that were felt significantly different between genders were related to the questions "I feel pleased with myself" and "I am a cheerful child", which both resulted in lower values for males and higher for females, that is, males have the perception of being more pleased with themselves and more cheerful than females.

3.3 Perception of well-being and noise disturbance in good and bad acoustics

Figures 4 and 5 show the mean values of the answers to the questions related to the perception of well-being in good and bad acoustics given by happy and unhappy children, respectively. Similarly, figures 6 and 7 show the mean values of the answers to the questions related to the perception of noise disturbance given by happy and unhappy children, respectively.

In each figure there is a direct comparison between answers given by pupils in good and bad acoustics. For happy pupils (figures 4 and 6), a tendency of measuring higher mean values, which correspond to worse conditions, in bad acoustics compared to good acoustics was found. Significant differences according to the MWU (p-values < 0.05), were found for the answers to the questions Q6_N, Q7_N and Q8_N, which relate to noise disturbance during silence tasks, and to intensity and disturbance during group activity, respectively. The results highlight the fact that noise in bad acoustics, either from outdoor or indoor, can be perceived as more disturbing being more amplified by higher reverberation. For unhappy students (figures 5 and 7) significant differences between answers in good or bad acoustics were only found with respect to aspects related to well-being perception. Particularly, differences were found for questions Q2_WB, Q5_WB and Q12_WB, which are related to self-esteem, emotional health and enjoyment at school, respectively.

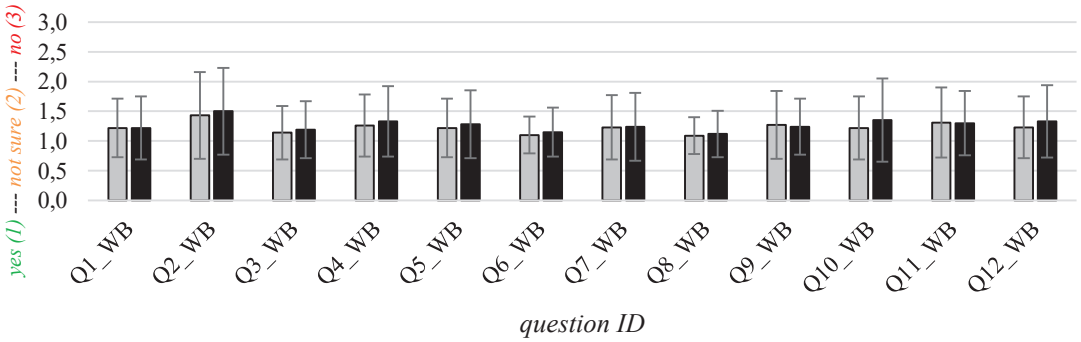

Figure 4 – Happy students' mean responses on the perceived well-being. Grey and black bins refer to answers given in good (124 students) and bad (172 students) acoustics, respectively. Error bars are the standard deviations across subjects.

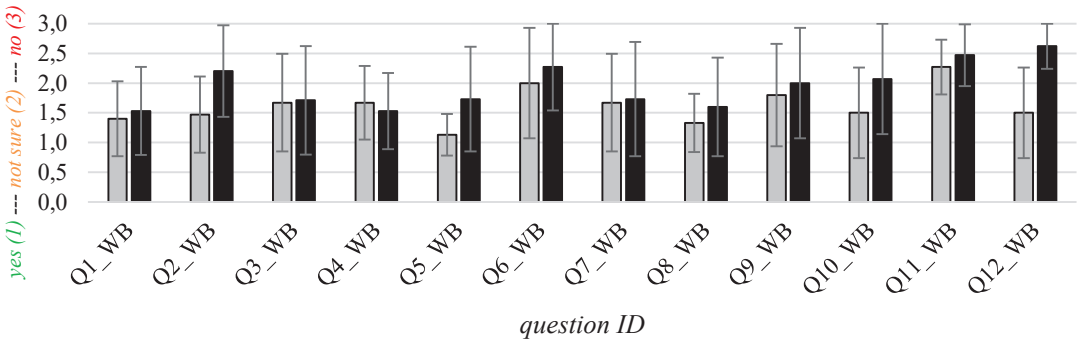

Figure 5 – Unhappy students' mean responses on the perceived well-being. Grey and black bins refer to answers given in good (15 students) and bad (15 students) acoustics, respectively. Error bars are the standard deviations across subjects.

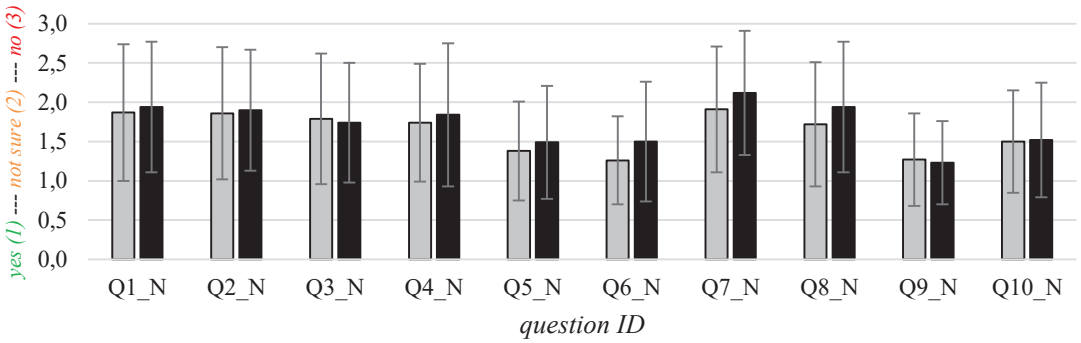

Figure 6 – Happy students' mean responses on the perceived noise disturbance. Grey and black bins refer to answers given in good (124 students) and bad (172 students) acoustics, respectively. Error bars are the standard deviations across subjects.

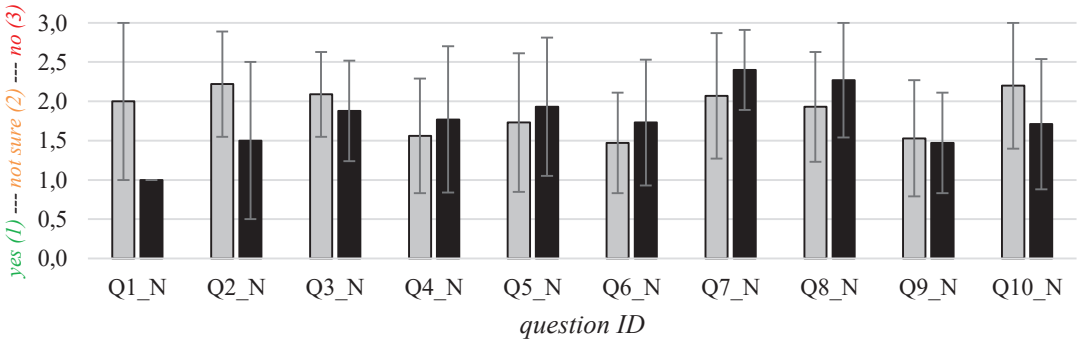

Figure 7 – Unhappy students' mean responses on the perceived noise disturbance. Grey and black bins refer to answers given in (15 students) and bad (15 students) acoustics, respectively. Error bars are the standard deviations across subjects.

A correlation analysis between objective and subjective data for happy children revealed a positive relationship between disturbance from noise coming from outside the classroom, and in particular from adjacent rooms and corridor (Q3_N), and the noise level measured when the children were in silence, $L_{Aeq,sil}$. This relationship is showed in figure 8 as a linear regression between the considered variables, well underling as low indoor sound insulation is related to higher sound levels in classrooms

and consistently higher perceived noise disturbance.

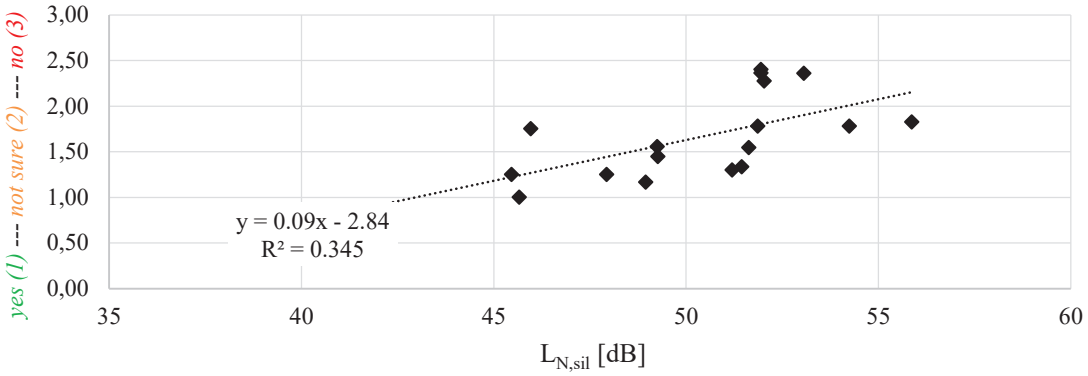

Figure 8 – Linear regression between happy students' mean responses to question Q3_N (i.e. "How much sounds of radios or recorders coming from other classrooms or from the corridor disturb you?") and measured noise level in silence ($L_{N,sil}$).

4. CONCLUSIONS

This work investigated the relationships between objective parameters related to primary school classrooms, i.e. reverberation time and noise as well as intrinsic classes characteristics, and the subjective impression of students related to their perception of well-being and noise disturbance at school. Results were obtained clustering the acquired data in terms of good or bad acoustics, based on a reverberation time threshold of 0.8 s that was set according to literature. Also, the subjective impressions of children were distinguished into answers from happy or unhappy students based on the judgements provided to the scale of happiness question.

The most important outcomes of the study can be summarized as follows:

- Happy children showed a tendency of giving more negative answers when they belonged classes in bad acoustics, compared to happy children in good acoustics, in the perception of noise disturbance at school;
- Unhappy students were strongly influenced by good or bad acoustics only with respect to aspects related to well-being, and particularly to self-esteem, emotional health and enjoyment at school;
- The disturbance from noise coming from adjacent rooms and corridor was found to be strongly correlated to the noise level measured when the children were in silence inside the classroom.

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