Long-term monitoring campaigns in primary school: the effects of noise monitoring system with lighting feedback on noise levels generated by pupils in classrooms

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ABSTRACT

Noise levels generated by pupils talking and moving greatly affect teaching and learning process in primary schools. Teachers tend to raise their voice level in order to improve intelligibility under noisy learning environment, negatively affecting their vocal health. More efforts need to be done to study an educational method to reduce chatting noise directly involving occupants' behavior. This study aimed to evaluate the effects on noise reduction generated by active involvement of the pupils in lowering their voice volume when advised by a noise monitoring system with lighting feedback, namely SEM (Speech and Sound SEMaphore). Monitoring campaigns were carried out over 3 scholastic years in 13 primary school classes (4÷5 for year) in Turin (Italy). The background noise level, L_{90}, was measured in two conditions with the lighting feedback of SEM switched off and on. The comparison between these conditions was analyzed for the overall classes for a total of 550 cases. The results showed an improvement in 51% of cases in terms of decrease of L_{90} mean values when SEM lighting feedback was on, where the average decrease of the L_{90} mean values was of about 3.0, 2.7 and 3.3 dB in first, second and third scholastic year, respectively.

Keywords: Noise, Classroom acoustics, Occupants' behaviour
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1. INTRODUCTION

Background noise levels and acoustic characteristics negatively influence learning and teaching process in classrooms. Researchers have demonstrated that teachers tend to use incorrect vocal behaviour under noisy conditions and poor acoustics in classrooms, generating voice problems. In their investigation on vocal doses and parameters of primary school teachers, Bottalico and Astolfi [1] found that vocal parameters increase according to growing of background noise level during traditional lessons. On the pupils' side, noise from outside and inside classroom has detrimental effects on academic performance. Shield and Dockrell [2] highlighted that noise generated by students leads to a decrease in nonverbal and verbal tasks, such as reading and spelling.

Noise generated by children during classrooms activities has been defined as the main source of noise in primary school [3-4]. Astolfi et al. [5] confirmed that student talking and moving were the highest perceived noisy source in primary school classrooms according to subjective investigation. Sato and Bradley [6] showed an increase in average noise levels by up to 10 dBA caused by students during teaching activities. Physical interventions in terms of acoustic materials are still the main tendency to improve acoustic comfort in classrooms, while a little number of studies have investigated the use of alternative methods, such as the installation of a visual feedback system in classroom, in order to directly involve teachers and students in reduction of background noise levels. Prakash et al. [7] highlighted that teachers, students and the management declared a positive and highly utility of a visual feedback system for improvement of learning process in classrooms. In an experiment conducted in three classes over 36 hours of classroom activities, Tonder et al. [8] demonstrated that the use of SoundEar II device [9] leads to a decrease of classroom noise levels, and an improvement in teaching process and classroom environment according to subjective assessments. Nevertheless, these previous studies on the effects of visual feedback have highlighted some limitations, such as the lack of objective measurements and the short time of monitoring campaigns, respectively.

The present study aims to present preliminary results of a long-term monitoring campaigns over three scholastic years in thirteen primary school in Turin (Italy) in order to investigate the effects of noise monitoring system with lighting feedback on noise levels generated by pupils during traditional lessons.

2. EXPERIMENT

2.1 The noise monitoring system with lighting feedback

The noise monitoring system with the lighting feedback, namely SEM (Speech and Sound SEMaphore) has been developed at Politecnico di Torino [10] in order to monitor and control noise levels inside the classrooms and to encourage an adjustment to occupants' behaviour, such as lowering voice volume. The variation of the coloured lighting feedback, which alternates between green, yellow and red, is controlled by an adaptive algorithm, that differs SEM from the existed devices, such as SoundEar device [9]. Indeed, it does not work based on pre-set noise limits because the algorithm adapts the lighting variation automatically according to the increase in the overall sound level. The adaptive algorithm allows the lighting feedback to became yellow or red when the noise levels are not extremely high, but they can generate annoyance compared to previous noise condition. Moreover, the background noise level (L_{90}) is recorded in order to filter the noise caused by the accidental events, such as sneezing and closing the door.

The totem version of SEM were located in front of pupils in each classroom in order to easily provide the lighting feedback during the teaching activities (Figure 1). The totem consists of a high transparent panel (70 x 160 cm) illuminated by a through-light colour beam for lighting feedback visualization and a sound level meter device for sound levels recording. A low-cost micro-controller board controls the lighting feedback and sends data to a server in real time.

Figure 1. The noise monitoring system with lighting feedback (SEM) located in classroom. Green represents acceptable background noise levels, yellow indicates an increase of them and red means that noise levels are high and annoying.

2.2 Classrooms

Monitoring campaigns were carried out over 3 scholastic years in a primary school in Turin (Italy), which is located in a residential area far from a heavy traffic road. The building was built at the end of the nineteenth century, and it has an old style and finishing with thick masonry walls. The classrooms face onto a quiet street or the internal courtyard and they have large windows, earthenware tiles on the floors and high ceilings with vaults. The geometry and materials are similar between the classrooms, which are acoustically treated. The walls are covered by plasterboard tiles (1.2 x 2.4 m, with a percentage of perforation of 16%) with an air gap of 7.5 cm from the walls, which detailed description is given in Astolfi et al. [11]. The average classrooms volume is 240 m^3. The reverberation time (T_{30}) has been measured in the school classrooms in compliance with the BS EN ISO 3382-1 standards [12], applying the integrated impulse response method. The mean reverberation time was 0.9 s in unoccupied condition and 0.6 s in occupied condition, the latter being simulated by using 100% polyester panels as to represent the presence of children seated [11].

2.3 Methodology

The details about monitoring campaigns are reported in Table 1. In particular, a total of twenty-five teachers (7÷10 for year) and thirteen school classes (4÷5 for year) with a different number of pupils from five to ten years old were involved. Two of these teachers were involved two twice over the years, while the pupils were changed each year. The duration of the third monitoring campaign was extended compared to the first and second ones to obtain more data, and the monitoring period corresponded to the working day (less than 8 hours).

Each monitoring campaign can be divided in two phases according to the variation of the lighting feedback of SEM. In the first one the noise monitoring system measured the background noise levels, but the lighting feedback was switched off, while it was switched on in the second phase.

The teachers were involved in the set-up of the monitoring campaigns, i.e. a training phase was performed in order to explain them the purpose of the noise monitoring system and the technical operation to its switching on and off. Moreover, they filled out a daily log book to note different variables, such as type of activity, name of teacher, number of pupils, time band, day of the week and the possible presence of high noise levels coming from outside, corridor or other classrooms. This information was used in order to exclude the random events and take into account the variables in the data analysis. Pupils were not aware of the purpose of the noise monitoring system in the first phase because an information campaign was carried out on the first day of the second phase with active lighting feedback aiming to show the relation between the colours of the warning light and the noise levels produced by pupils themselves. The method encouraging pupils to control their voice volume over the weeks were changed between the three monitoring campaigns. In the first ones a defined method was not introduced, while in the second scholastic year a mobile app was provided to teachers allowing them to visualize and communicate to pupils the results in terms of number of green, yellow and red light colours given by SEM during the day. Moreover, the app was used by researchers as a tool for organizing a game-based challenge between the four classes. According to needs of teachers this method was changed in the third monitoring campaign, where the researchers communicated to each classes the trend of green, yellow and red light colours every Monday drawing a graphic on the board and delivering a report with the results of the week.

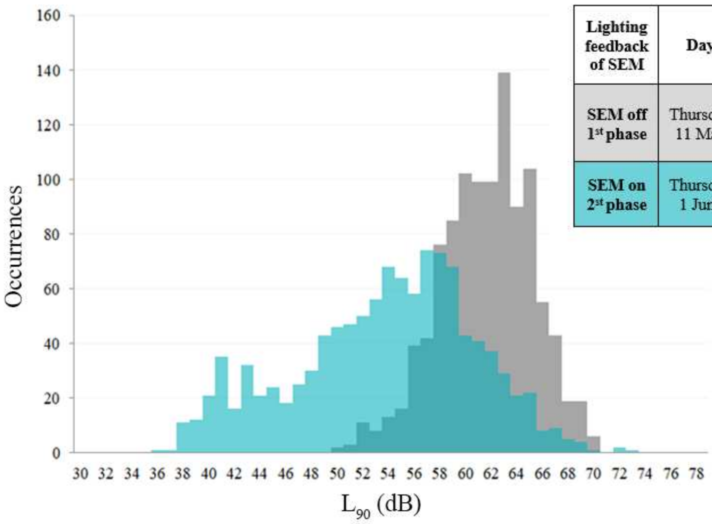
Table 1. Main characteristics of each monitoring campaign subdivided for classes.

Monitoring campaign	**Scholastic year**	**Number of week**		**Class (ID)**	**Teachers' Number**	**Pupils' number**
		SEM off 1st phase	**SEM on 2nd phase**			
First	2015 - 2016	2	4	II (A)	2	23-25
				III (B)	1	20-22
				IV (C)	2	20-26
				V (D)	2	21-26
Second	2016 - 2017	2	4	I (E)	3	16-20
				II (F)	2	20-25
				III (G)	3	18-21
				IV (H)	2	19-21
Third	2017 - 2018	6	9	I (I)	2	19-24
				I (L)	2	18-22
				II (M)	2	10-14
				II (N)	2	19-26
				IV (O)	2	16-19

3. STATISTICAL ANALYSIS

A statistical analysis was performed by MATLAB (R2014b, version 8.4) According to Siegel and Castellan [13], a non-parametric method should be used to analyse data of two groups of independent observations that have a not normal distribution. A Mann-Whitney U Test (MWU) was assessed to evaluate the significance of the differences between the occurrences distribution of background noise levels (L_{90}) measured in the first and second phase, without and with lighting feedback, respectively. These paired samples of data were selected according to the following characteristics: same teacher, time band, day of the week, lesson typology, and similar number of pupils. The total of 550 paired samples for overall classes are found. The traditional lessons were only analysed in this study. The time band related to each paired sample compared depends on the information noted by teachers on daily log books.

An example of occurrences distribution of L_{90} values of two data samples related to a pair of the days and the results of statistical test was reported in Figure 2. An improvement, that is the pair of days in which L_{90} values decrease significantly in the day with the lighting feedback of SEM switched on (one-tailed *p*-value < 0.05 with 95% confidence interval), was obtained. The total number of significant improvements obtained for each class (278) in relation to the total paired samples (550) and the average significant decrease of the L_{90} mean values was stated in Table 2.



Lighting feedback of SEM	Day	L_{90} (dB) Mean	Median	Mode	Rank mean	MWU *p*-value (1 tailed)
SEM off 1st phase	Thursday 11 May	61.6	62	63	1477	0.00
SEM on 2nd phase	Thursday 1 June	53.7	55	57	725	

Figure 2. An example of occurrences distribution of L_{90} of two data samples related to a pair of the days with the lighting feedback switched off and on. The results of descriptive statistics and of MWU Test were reported in the table for each data sample.

4. RESULTS

Table 2 shows that an improvement in terms of decrease of L_{90} mean values when lighting feedback of SEM has been obtained in 51% of pair of the days, that were compared through the MWU Test. Moreover, the average decrease of the L_{90} mean values was of about 3.0, 2.7 and 3.3 dB when the visual feedback was switched on in first, second and third monitoring campaign, respectively. Standard deviations of the variation of the average L_{90} mean values were higher in the second monitoring campaign compared to the other ones. The differences of L_{90} mean values between phase one, with visual feedback switched off, and phase two, with it switched on, were higher in the second (A), third (G) and first (L) grade classes over the three monitoring campaigns, with average difference on L_{90} mean values of 3.9, 5.0 and 4.0 dB, respectively. Except for second (A) grade class, the use of S&N-S Light leads to a much decrease of L_{90} values when the noise levels were higher during the traditional lessons without the noise monitoring system.

Regarding to the improvements in terms of decrease of L_{90} mean values the higher percentages were also obtained in the same grade classes over the three monitoring campaigns, as Figure 3 shows. In particular, the results showed an improvement in 67%, 50% and 63% of cases in second (A), in third (G) and in first (L) grade classes, respectively. According to the average decrease of the L_{90} mean values, Figure 3 highlights that the percentages of improvements were lower in the second monitoring campaign and higher in the third ones, with a range of values from 20% to 50% and 38% to 53%, respectively.

Table 2. The average of $L_{90,mean}$ values related to statistically significant improvements of first and second phase with standard deviation reported in the bracket and the differences in $L_{90,mean}$ values between the both phases. The number of statistically significant improvements in relation to the total pair of the days compared through the MWU Test were also reported.

Monitoring campaign	**Class (ID)**	**$L_{90,mean}$ (st.dev)**		**$\Delta L_{90,mean}$**	**Improvement/ total paired samples**
		SEM on 1st phase	**SEM off 2nd phase**		
First	II (A)	50.8 (2.6)	47.6 (2.7)	-3.9	10/15
	III (B)	49.3 (0.7)	46.7 (0.6)	-2.6	3/9
	IV (C)	50.8 (1.9)	47.9 (2.5)	-2.9	12/19
	V (D)	54.1 (4.8)	51.1 (1.9)	-2.9	3/7
		51.0 (2.6)	**48.0 (2.6)**	**-3.0**	
Second	I (E)	54.6 (0.1)	53.1 (1.4)	-1.5	2/10
	II (F)	53.4 (4.2)	52.0 (4.1)	-1.4	6/25
	III (G)	57.7 (5.2)	52.6 (5.5)	-5.0	5/10
	IV (H)	57.7 (2.5)	55.1 (1.9)	-2.5	5/12
		55.9 (4.1)	**53.2 (3.8)**	**-2.7**	
Third	I (I)	57.7 (2.3)	54.3 (2.7)	-3.4	65/103
	I (L)	58.4 (2.5)	54.4 (3.0)	-4.0	15/26
	II (M)	57.5 (7.6)	54.9 (2.6)	-2.7	71/142
	II (N)	54.2 (3.4)	50.4 (2.2)	-3.9	45/75
	IV (O)	57.5 (2.4)	55.0 (2.3)	-2.6	36/94
		57.1 (1.63)	**53.8 (1.92)**	**-3.3**	

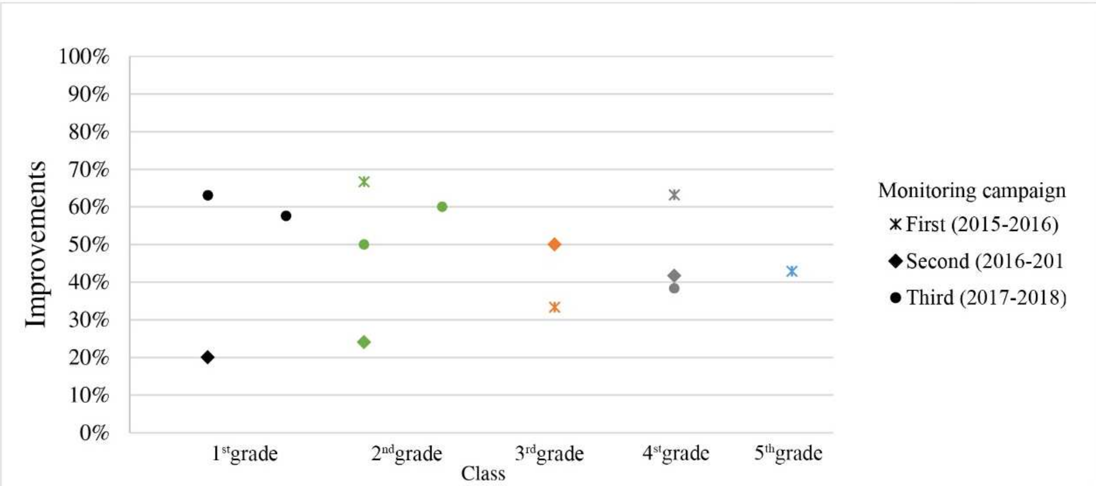


Figure 3. The percentage of statistically significant improvements in terms of L_{90} according to the grade classes and the scholastic year of monitoring campaigns.

5. CONCLUSIONS

The present study has investigated the effects of the use of a noise monitoring system with lighting feedback on the decrease of noise levels generated by pupils during traditional lessons. Thirteen classes of a primary school in Turin (Italy) and fifty-five teachers were involved in a long-term monitoring campaigns over three scholastic years.

A decrease of background noise levels was found when the visual feedback of the noise monitoring system was switched on. A trend of improvements in terms of L_{90} mean values was not obtained according to the age of pupils, indeed the more positive effects of the presence of the visual feedback in noise monitoring system were found in different grade classes over three scholastic years. However, further investigations are required in order to investigate how the age of pupils and other possible variables, such as teachers, motivational method, number of pupils in classrooms, can affect the decrease in background noise.

Moreover, a subjective investigation on the utility of the monitoring system and the monitoring of teachers' voice parameters in presence of the visual feedback were carried out in the third monitoring campaign. Therefore, the comparison between subjective data, voice parameters and the decrease of the background noise levels will be investigated in the future works.

The preliminary results demonstrate the positive effects of an educational tool based on the visual feedback to reduce the noise levels generated by pupils in classrooms encouraging the use of positive behaviours, such as the lowering of voice levels.

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7. REFERENCES

1. Bottalico P. and Astolfi A. *"Investigations into vocal doses and parameters pertaining to primary school teachers in classrooms"*, The Journal of the Acoustical Society of America, 131 n. 4 (2012)., pp. 2817-2827. - ISSN 0001-4966

2. Shield B. and Dockrell J. E., "*The effects of environmental and classroom noise on the academic attainments of primary school children"*, The Journal of the Acoustical Society of America**,** 123 (2008), pp.133-144

3. Shield B. and Dockrell J. E., "*External and internal noise survey of London primary schools"*, Journal of the Acoustical Society of America**,** 115 (2004), pp.730-738

4. Shield B. and Dockrell J. E., "*The effects of noise on children at school: A review"*, Building Acoustics, 10 (2003), pp. 97-116

5. Astolfi, A. and Pellerey F., "*Subjective and objective assessment of acoustical and overall environmental quality in secondary school classroom"*, The Journal of the Acoustical Society of America, 123 (2008), pp.163-7173

6. Sato, H. and Bradley, J.S., *"Evaluation of acoustical conditions for speech communication in working elementary school classrooms",* The Journal of the Acoustical Society of America 123, 2064 (2008), pp. 1187-119

7. Prakash S., Rangasayee R. and Jeethendra P., *"Low cost assistive noise level indicator for facilitating the learning environment of school going learners with hearing disability in inclusive educational setup*", Indian Journal of Science and Technology 4(11), (2011), pp. 1495-1504

8. Jessica van Tonder J.V., Woite N., Strydom S.; Mahomed F.; Swanepoel D.W., *"Effect of visual feedback on classroom noise levels",* South African Journal of Childhood Education, 5 (2015)

9. SoundEar. Available online: https://soundear.com/ (accessed on 24 February 2019)

10. https://www.knowledge-share.eu/en/ (accessed on 24 February 2019)

11. Astolfi A., Puglisi G. E., Pavese L., Carullo A., *"Long-term vocal parameters of primary school teachers and classroom acoustics with and without an acoustical treatment",* In Proceedings of Forum Acusticum, Krakòv (2014)

12. UNI EN ISO 3382-1, *“Measurement of room acoustic parameters - Part 1: Performance spaces”,* International Organization for Standardization, June 2009;
13. Sigel, S.; Castellan, N.J. *Non Parametric Statistics for the Behavioral Sciences*, 2nd ed.; McGraw-Hill: New York, NY, USA, 1988