Long-term Monitoring of Irrelevant Speech Noise in Open-plan Offices with and without Lighting Feedback to the Occupants

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LONG-TERM MONITORING OF IRRELEVANT SPEECH NOISE IN OPEN-PLAN OFFICES WITH AND WITHOUT LIGHTING FEEDBACK TO THE OCCUPANTS

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ABSTRACT

Irrelevant speech noise is one of the main sources of noise that negatively affect health, well-being, comfort and performance in densely occupied environments. The use of devices that provide lighting feedback based on noise levels generated by occupants could promote a change in their behavior and therefore an improvement of acoustic conditions. In the present work, a four-weeks monitoring campaign was performed in two bank open-plan offices in Milan (Italy) with six S^{3}EM (Speech and Sound SEMaphore) devices. S^{3}EM monitors noise levels and visualizes their variation through an integrated colored lighting feedback (i.e., red, yellow and green) based on the results of an advanced algorithm. In the first and fourth weeks the lighting feedback was off, in the second and third weeks it was on, to evaluate the lighting feedback effect on occupants. The ethnographic observation method was applied to describe interactions of occupants with the task, the work environment and with the S^{3}EM devices. Results show that the sound level decreased only when users had the possibility to control their voice in relation to the work activity performed.

Keywords: *irrelevant speech noise, offices, lighting feedback, ethnographic observation method*

1. INTRODUCTION

The noise generated by conversations is one of the main causes of occupant annoyance in open-plan offices. Symptoms such as headaches, concentration difficulties, fatigue, reduced productivity and motivation loss are negative factors related to such environments [1, 2]. Acoustic comfort is influenced by the office architectural characteristics, which must respond to a complex compromise between speech intelligibility and speech privacy [3], but also by the users' vocal behavior. A methodology to control the sound levels generated by speech could be used to encourage workers towards proactive behavior aimed at increasing acoustic comfort and well-being. The present work assessed the effectiveness of S^{3}EM (Speech and Sound Semaphore), a device developed

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and validated at the Politecnico di Torino for the detection and visualization of sound levels through a green, yellow or red lighting feedback, in order to actively involve users by encouraging their vocal output control when indicated. The method of ethnographic observation was applied to understand users' attitude towards the work activity to be performed, the working environment and the S^3EM devices introduced.

2. MATERIALS AND METHODS

The activity was carried out over four weeks in November 2022 in two open-plan offices of a bank in Milan, called "1" and "2", respectively characterized by twelve and ten workstations. The activity carried out by office workers mainly involved monitor activities and online meetings (calls), which had the main impact on environmental noise. In particular, in office "1" the activities carried out, related to HR management and recruiting, were "individual" and required less need to collaborate with colleagues; instead, in office "2" the activities, linked to HR transformation and management of organizational communication, were carried out in team and required collaboration with colleagues and suppliers.

The experimental campaign was organized into three main activities: i) acoustic monitoring, ii) ethnographic observation, iii) analysis of the results. The latter was performed using the Mann-Withney U Test and the median test with independent samples.

2.1 Acoustic monitoring

The acoustic monitoring was performed by means of six S^3EM devices (three for each office), placed on the desks between four workstations. This instrument supplies the lighting feedback according to an adaptive algorithm, which allows it to pass from green to yellow and red based on the difference in dB between the level measured in each instant compared to the level averaged over the previous seconds. However, it can also be used with the "maximum levels" method, according to which the color of the signal changes from green to yellow and red when a predetermined sound level is exceeded. The S^3EM were in operation during working hours (9:00-17:00) from Monday to Friday. The time considered useful for the analyses, to overcome any device ignition problems encountered on some days, is from 11:00 to 16:00. The analysis of the acoustic data was carried out on the A-weighted equivalent sound pressure levels (L_{Aeq}) averaged over 15 minutes. Once this first analysis was carried out, the two S^3EM (one for each office) which monitored the most critical conditions were selected.

Tab. 1 shows the details of the measurement campaign and the algorithms used with the respective thresholds set for the lighting feedback color change. The S^3EM were in operation in the two offices for four weeks, but the lighting feedback was limited to the central two weeks. This choice was determined by the desire to verify the effectiveness of the lighting feedback in relation to the change in user behavior.

Table 1. Details on the use and operation of the S^3EM over the four weeks: lighting feedback (LF) ON or OFF, type and thresholds of the implemented algorithms.

Period	LF	Algorithm	Thresholds
7 – 11 nov.	OFF	Adaptive 1	Red: $L_{Aeq} - L_{A,rif} \geq 8$ dB Yellow: 4 dB $\leq L_{Aeq} - L_{A,rif} < 8$ dB
14 nov.	ON	Adaptive 1	
15 – 18 nov.	ON	Adaptive 2	Red: $L_{Aeq} - L_{A,rif} \geq 10$ dB Yellow: 5 dB $\leq L_{Aeq} - L_{A,rif} < 10$ dB
21 nov.	ON	Maximum levels 1	Red: $L_{Aeq} = 65$ dB Yellow: $L_{Aeq} = 55$ dB
22 – 25, 28, 29 nov.	ON	Maximum levels 2	Red: $L_{Aeq} = 60$ dB Yellow: $L_{Aeq} = 50$ dB
31 nov. – 2 dec.	OFF	Maximum levels 2	

2.2 Ethnographic observation

For what concerns the ethnographic observation, the data collection protocol was built on the basis of the scheme contained in the UNI EN ISO 10075:1 2018 [4] standard, with the aim of characterizing the activities carried out within the identified spaces, identifying those that lead to an increase in noise, and describe user interaction with S^3EM.

3. RESULTS

3.1 Acoustic monitoring and ethnographic observation

The first objective was to identify whether the sound level decreased when the S^3EM were ON with respect to when were OFF. In office "1", the A-weighted averaged sound pressure levels recorded in the entire monitoring period were 53.0 dB (st. dev. = 5.8 dB) with S^3EM OFF and 49.0 dB (st. dev. = 4 .5 dB) with S^3EM ON, while in office "2" were 52.8 dB (st. dev. = 6.4 dB) and 51.7 dB (st. dev. = 4.1 dB), respectively. The Mann-Withney U Test and independent-samples median test reported p-value = 0.000

and p-value = 0.000 for office “1”, p-value = 0.023 and p-value = 0.748 for the office "2".

The difference found between the two offices was traced back to the different type of activity performed: in office "1" a lower number of calls were made (with an average duration of 16 minutes), whereas in office "2" a larger number of calls (with an average duration of 42 minutes) were made.

Based on the results obtained through ethnographic observation, further analyzes were carried out on the relationship between the sound level and the number of people present in the office and between the sound level and the number of people simultaneously in call. The tolerability threshold declared by the users relating to the maximum number of people in call at the same time is equal to three (defined cut-off level). Tab. 2 and Tab. 3 report the main results of this survey.

The results for office "1" and office "2" demonstrate that the sound level:

- increases as the number of people increases;
- for the same number of people it is lower with S^{3}EM ON than with S^{3}EM OFF;
- increases as the number of people in call increases;
- cut-off is equal to 55 dB(A);
- with the same number of people in call, it is the same with S^{3}EM ON compared to S^{3}EM OFF.

Table 2. Relationship between the number of people (NP) present in the office and L_{Aeq} measured, in office "1" and in office "2", with S^{3}EM ON and S^{3}EM OFF.

	Office “1”						Office “2”					
	S^{3}EM ON			S^{3}EM OFF			S^{3}EM ON			S^{3}EM OFF		
NP	L_{Aeq} [dB]	N slot	Dev. St. [dB]	L_{Aeq} [dB]	N slot	Dev. St. [dB]	L_{Aeq} [dB]	N slot	Dev. St. [dB]	L_{Aeq} [dB]	N slot	Dev. St. [dB]
1	45.6	9	1.1	-	-	-	-	-	-	-	-	-
2	46.1	18	2.5	-	-	-	-	-	-	-	-	-
3	49.9	8	4.8	51.5	6	4.8	51.0	8	3.3	56.1	8	3.7
4	49.2	6	3.9	54.6	7	2.8	51.0	18	2.8	53.7	6	2.8
5	55.0	3	2.0	-	-	-	54.7	3	6.7	-	-	-
6	55.5	6	2.4	-	-	-	55.2	12	5.8	-	-	-
7	51.8	6	2.2	-	-	-	56.6	11	3.6	-	-	-
8	-	-	-	-	-	-	56.7	7	4.7	-	-	-
9	-	-	-	-	-	-	55.0	4	3.4	-	-	-
10	-	-	-	-	-	-	57.0	6	2.4	-	-	-

Table 3. Relationship between the number of people in call in the office (NPc) and L_{Aeq} measured, in office "1" and in office "2", with S^{3}EM ON and S^{3}EM OFF.

	Office “1”						Office “2”					
	S^{3}EM ON			S^{3}EM OFF			S^{3}EM ON			S^{3}EM OFF		
NPc	L_{Aeq} [dB]	N slot	Dev. St. [dB]	L_{Aeq} [dB]	N slot	Dev. St. [dB]	L_{Aeq} [dB]	N slot	Dev. St. [dB]	L_{Aeq} [dB]	N slot	Dev. St. [dB]
0	46.6	37	3.0	50.5	14	5.0	55.3	18	5.3	54.0	2	5.7
1	52.5	14	1.8	52.5	13	2.8	51.1	16	4.0	53.0	2	7.0
2	55.0	3	3.0	54.6	7	2.6	53.6	14	3.9	54.8	10	2.8
3	56.5	2	0.7	-	-	-	54.8	12	3.7	-	-	-
4	57.5	2	0.7	-	-	-	55.0	4	3.6	-	-	-
5	-	-	-	-	-	-	59.0	5	1.0	-	-	-

4. CONCLUSIONS

Irrelevant speech noise in densely occupied environments is one of the main sources of noise that negatively affect health, well-being, comfort and work performance. The present work consisted in a four-weeks acoustic monitoring campaign in two open-plan offices of a bank in Milan. Three S^{3}EM devices were put in each office to monitor noise levels and provide users with a lighting feedback (red, yellow and green) based on the results of an advanced algorithm. The ethnographic observation method was applied to describe interactions of occupants with the task, the work environment and with the S^{3}EM. The results show that a system able to notify users that they need to change their vocal behavior is effective when the work activities performed allow it. The sound level was lower with S^{3}EM ON than with S^{3}EM OFF with differences equal to 4 dB in office "1", while no significant differences were found in office "2" due to the different work performed. Furthermore, no sound level reductions are observed when users are in call, both with S^{3}EM ON and with S^{3}EM OFF. Future studies will aim to further investigate the sound levels in relation to the different activities carried out in an open-plan office.

5. REFERENCES

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