

Providing Acoustic Comfort in the Classroom Using Double-Glazed Windows and its Effect on Students Stress

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Abstract

Background: Students spend a considerable amount of time at school; thus, noise pollution can have negative physical and emotional effects on them.

This study aimed to determine the association between reduced noise by changing single-glazed to double-glazed windows and stress level changes among students.

Methods: We included 384 male high school students in this study to specify the effect of noise reduction (using double-glazed windows) on classroom stress in Shiraz, 2018-2019 academic years. The participants were randomly selected from schools exposed to unauthorized noise; they were divided into control (N=192) and intervention groups (N=192). Using the Perceived Stress Scale (PSS), we assessed stress perception in a semi-experimental pretest and posttest design. Moreover, UT-353 digital sound level meter was used to measure noise pollution.

Results: The mean pretest and post-test scores for the intervention group were 29.30+6.878 and 24.88+8.711, respectively. The acoustic comfort induced by double-glazed windows could significantly decrease the level of stress ($P<0.001$). The researchers used mean statistics and standard deviation for descriptive data analysis and Independent t-test for inferential analysis. The results showed a significant difference between the intervention and control groups.

Conclusions: Replacing single-glazed windows with double-glazed ones improved the acoustic condition of the classroom, thereby reducing the stress of male high school students.

Keywords: Psychology, Noise pollution, Students, Stress, Schools

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1. Introduction

Kryter defines “noise” as “An audible acoustic energy that adversely affects the physiological or psychological well-being of people”. For humans, the generally accepted standard hearing range for humans is 20 to 20,000 Hz (1). Different methods and units have been employed to quantify sound. The decibel (dB) is a logarithmic unit used to measure sound level and one decibel is the threshold of hearing (2). The A-weighted filter (dBA) is typically applied to better simulate human response to sound and noise across frequency; it is also used for a wide range of typical sound levels, assessing loudness and compensating for human ear’s lower sensitivity to lower frequency and very high-frequency sounds (2, 3).

Noise pollution could cause different problems for people of any age and in any location, and students are no exception here. Over the recent years, a large number of studies have been conducted on the negative effects of noise on students, such as disturbance in learning, concentration, attention, memory, motivation, speech

intelligibility, reading, and academic performance (4-7). In addition, students’ physical and mental health may also be affected by noise pollution, which has been discussed by researchers (8).

Classroom noise pollution is caused by 1) external sources, such as street noise, aircraft and train noise, industrial noise, and construction noise and 2) internal sources, including the noise caused by student activity, the mechanical and electrical equipment used for cooling or heating the classroom, and teaching equipment such as projectors and computers (9).

Both students and teachers suffer from noise in the classroom. Teachers are forced to speak more loudly, possibly entailing leading to voice disorders. For a healthy educational environment, it is essential that teachers and students be physically and mentally healthy. The optimal noise level in the classroom is less than 35 dB according to the World Health Organization (WHO) standards (10, 11).

Improving the acoustics of classrooms in educational

buildings has always been one of the most important goals of school designers. Sometimes, it is not possible to remove the environmental noise but its reduction could help improve the acoustics of the building. Sound insulation is among the suggestions of designers for acoustic comfort. Ceiling, facade of the building, and type of windows can be very effective in controlling sound transmission. Therefore, optimized design and selection of appropriate materials and windows can help to control the noise input.

Zannin and Marcon (2007) simulated non-acoustical treatment classroom in the suburbs of Curitiba, Brazil. They selected different materials such as Gypsum, Plywood, and Perforated Plywood for simulation. The simulations of reverberation time have demonstrated that a simple acoustical treatment of the ceiling would significantly improve the reverberation time inside the classroom. The classrooms would turn acoustically acceptable, according to the values of reverberation time established not only by the Brazilian Standard NBR 12179, but also by standards of other countries (12).

Single-glazed window was not a suitable sound insulation, so a double-glazed window has been replaced with the aim of providing acoustic comfort. Many studies have numerically concluded or experimentally reported that double-glazed windows significantly reduce the noise pollution inside the buildings (13-16).

Stress is a negative impact of noise pollution, which falls under the category of non-auditory disadvantages, and has a devastating effect on academic achievement in the educational environment (17, 18). Several studies have identified noise pollution as an environmental stressor (19, 20).

Wallas and his colleagues (2018) investigated the effect of road traffic noise on saliva cortisol level as a stress biomarker hormone. Noise exposure levels were estimated at the most exposed facade of the residential buildings of the study subjects at the time of saliva sampling. According to the results, saliva cortisol levels appeared particularly high among those who were highly annoyed and exposed to road traffic noise levels (21).

Furthermore, Wälinder and his colleagues (2007) studied the effect of classroom noise pollution on stress reaction among fourth grade students. Stress was studied via symptoms of headache and fatigue, systolic blood pressure (SBP), and cortisol hormone levels. According to their results, non-standard acoustic status

of classroom had a negative impact on health, which was indirectly or directly related to stress reaction among students (22).

Given the prevalence of stress among students, it is necessary to investigate environmental strategies to reduce stress in educational buildings.

This research aimed to investigate the effects of noise reduction on the stress of male high school students. Sound insulation was done by replacing single-glazed windows with double-glazed windows. We focused on schools located in high noise pollution urban areas.

2. Methods

2.1. Study Setting

We conducted the present study in Shiraz, 2018-2019 academic years. The statistical population included all male high school students. The sample size was 384, calculated by Cochran formula, and the sampling method was multi-stage cluster sampling. This article is part of a research project that has been approved under the number "26348" in the Islamic Azad University, Beyza Branch.

According to the noise pollution maps of Shiraz, provided by Talaiekhosani and his colleagues (2018) (23), the urban areas where the average noise pollution was more than 63.4 (dB) at 8 AM and more than 61.5 (dB) at 13 PM, were represented by a red ribbon in the graphical map: Eram square, Artesh, Daneshjoo, Siboye, Shahid Mofateh, Cinema Sadi, Shishegari, Fergas, Lotfalikhan Zand, Parseh Square, Shohada Square, Shahid Shirodi Square, Nasr Square, Namazi Square, Vali Asr Square, Atlasi Square, Azadi, Jomhori, Chamran, Hazrati, and Tawos Square.

Since the objective was to control the noise pollution by switching windows, which should be done with the schools' own budget, samples were selected from nongovernmental schools. All nongovernmental male high schools with single-glazed windows located in the mentioned red areas were identified. Meetings were then held with school administrators to inform them about the harmfulness of noise pollution in their school classrooms. However, only two schools accepted to participate in this study.

First, the sound level of all classes in the two schools was recorded for one week by the sound meter to identify the classes with the highest degree of noise

pollution. Of 24 classrooms, 12 had an unauthorized noise pollution according to school audio standards. Classes that were closer to the street seemed to have more noise pollution compared with others.

2.2. Noise Measurement

UT-353 digital sound level meter was used to measure noise pollution in classrooms. Its measurement range was 30-130 dBA, shown numerically on the device monitor. Acoustic status of the classrooms was recorded one month before the windows were replaced and one month after (for one day of the week). Noise measurements were performed twice a day. In the first stage, it was performed from 7:00 am -7:10 am, and in the second stage, from 1:00 pm - 1:10 pm, when students were not present in the classroom. This measurement was intended to determine the effect of windows replacement on improving sound insulation in the intervention group. Since the aim of the study was to measure noise pollution with an external source (not internal noise pollution caused by student noise), sound measurement was performed in the classroom when students were not in the classroom. (Before the lesson begins: 7:00 am-7:10 am and after finishing the last class: 1:00 pm-1:10 pm. Moreover, classroom door and windows were closed. Of note, no acoustical treatment was used in the selected classrooms. The sound meter was positioned right in the gravity center of each classroom.

2.3. Stress

To evaluate the stress level among students, Perceived Stress Scale (PSS), in the form of questionnaires, was completed by students, pre-posttest. PSS is a well-known and extensively used questionnaire that evaluates the respondent’s perceived stress. The 10-item PSS comprised questions regarding the thoughts and feelings of students within the past month. Example questions revolved around how often the students felt “stressed or nervous” or “unable to control important things”. Five-point Likert scale

(0=Never, 4=very often) was used. The maximum PSS score is 40 and the minimum score is 0. Based on the total score, the items were classified into four levels: No Stress (0-10), Mild Stress (11-20), Moderate Stress (21-30), and severe Stress (31-40) (24). A significant number of studies have reported acceptable levels of reliability and validity (25, 26).

2.4. Statistical Analysis

Demographic data were summarized with descriptive statistics, means and SD. Independent t-test analysis was used for inferential statistics. Data analyses were carried out using Statistical Package for the Social Sciences (SPSS) Version 21.

3. Results

A total of 192 intervention and 192 control participants completed PSS as pretest and posttest stages. The mean ages of the intervention and control group were 17.03± 1.87 and 17.12±1.03, respectively. The students’ other demographic characteristics are shown in Table 1. No significant differences were found between the groups in terms of demographic data (age, family population), confirming that the two groups were comparable in terms of their demographics. None of the students had a history of auditory weakness in either group.

Table 2 shows the mean and standard deviations (SD) for the noise level scores of intervention and control groups one month pretest and one month posttest. There was no statistical difference in terms of the means prior to the intervention. The results of noise level analysis showed no significant differences for the intervention group over a period of ten minutes at 7 AM in the absence of students (P<0.001). In addition, no significant differences reported for the intervention group over a period of ten minutes at 1 PM (P<0.001). This indicates that the replacement of windows in the intervention group reduced noise pollution in the classroom.

Table 1: Demographic data of intervention and control groups of students

Parameter	Mean±SD		P
	Intervention (n=192)	Control (n=192)	
Age (years)	17.03±1.87	17.12±1.03	P<0.001
BMI (Kg/m ²)	23.83±2.85	23.14±2.34	P<0.001
Family monthly income (Rial)	35000000	3250000	P<0.001
Family population	4±1.03	4±0.06	P<0.001

SD: Standard division/ BMI: Body mass index

Table 2: Noise level pretest and posttest mean± SD by group

Groups	L_{Aeq} (db)(7:00-7:10 _{AM})		P	L_{Aeq} (db) (1:00-1:10 _{PM})		P
	Mean±SD			Mean±SD		
	pretest	post test		pretest	posttest	
Intervention classes	48.12±2.43	34.87±2.12	P<0.001	49.91±2.31	35.32±2.86	P<0.001
Control classes	48.30±2.87			48.3±1.62		

Table 3: Paired Sample T-test results of PSS at pre-test and post-test

Groups	PSS			t	P
	pretest	posttest			
Intervention	29.30±6.878	24.88±8.711		10.05	P<0.001
Control	29.14±6.656	29.53±6.683		1.02	0.0561

PSS: Perceived Stress Scale

The mean PSS score in the intervention group was 29.30±6.878 at pretest and 24.88±8.711 at posttest (P<0.001). Also, in the control group, the PSS score was 29.14±6.656 at pretest and 29.53±6.683 at posttest (0.0561). As observed in Table 3, reduction in noise pollution was effective in reducing the students' stress.

4. Discussion

Students' mental health is an important issue which is undoubtedly affected by noise pollution. Considering acoustic comfort in the early stages of designing can be very effective in reducing the damages caused by noise pollution. For instance, the location of the school's building site, selection of materials according to the sound absorption coefficient helps to achieve this goal.

We hypothesized that the acoustic comfort induced by double-glazed windows helped students feel relaxed and reduced their perceived stress score.

Both study schools were located close to the main streets, exposing the students to high levels of noise pollution. On the other hand, there was no noise control equipment for classroom sound insulation.

Study results showed that PSS significantly decreased in the intervention group, suggesting that double-glazed windows can be conducive to acoustic comfort and reduction in stress.

The results of this study were consistent with studies that confirmed the link between noise pollution and stress.

Some organizations around the world have set up standards about the level of classroom noise. According to the design standards of the school renovation organization in Iran, the maximum level of

Leq (equivalent continuous sound level) for a classroom is 55 dB (27). Meanwhile, other organizations such as WHO have recommended that the noise level be less than 35 dBA in empty classrooms and 40-50 dBA for occupied classrooms(28). Given that the purpose of this study was to investigate noise with external sources, like the traffic noise and not noise pollution with an internal source such as student noise in the classroom. Noise measurements were performed in an empty class, before the start of the class in the morning and at the end of the last class.

Limitations

The main limitation of the present study was the inclusion of male students only. Thus, the results could not extrapolate to the general population. The duration of the present study was one month, and the stress level was measured by a PSS questionnaire. There is a need for further research into the short term effects of noise pollution on the students' stress. This can be investigated by studying the changes in the levels of biological indicators such as cortisol and alpha-amylase. Finally, this study was unable to consider this issue among other educational levels due to the high costs of window replacement.

5. Conclusion

There might be many schools that are not built according to acoustic standards, particularly in less developed and developing countries. The classroom noise levels across the two investigated schools were higher than WHO permissible levels for schools and academic environment. We recommend that schools located in areas with high levels of noise pollution be identified by education officials. The windows in the facade of the buildings play an undeniable role in sound insulation; therefore, the replacement of single-glazed

windows with double-glazed ones can greatly improve the acoustic of the classroom, thereby reducing the stress caused by noise pollution among male high school students. To achieve this goal, the public sector and the Ministry of Education have to allocate funds for school acoustic upgrades because providing acoustic comfort is one of the basic needs of students.

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Ethical Approval

This article is part of a research project that has been approved under the number "26348" in the Islamic Azad University, Beyza Branch. Also, Written informed consent was obtained from students' parents.

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Conflicts of interest: None to declare.

References

- Kryter KD. The effects of noise on man. London: Academic Press; 2013.
- Ana GR, Shendell DG, Brown G, Sridhar M. Assessment of noise and associated health impacts at selected secondary schools in Ibadan, Nigeria. *J Environ Public Health*. 2009;1-6. doi: 10.1155/2009/739502. [PubMed: 20041025].
- Snow FJ. American Society Of Heating, Refrigeration, And Air Conditioning Engineers (ASHRAE) Thermographic Standard 101 P. Thermal Infrared Sensing Applied to Energy Conservation in Building Envelopes; 1982. International Society for Optics and Photonics. 1982. doi: 10.1117/12.932959.
- Shield BM, Dockrell JE. The effects of environmental and classroom noise on the academic attainments of primary school children. *J Acoust Soc Am*. 2008; 123(1):133-44. doi: 10.1121/1.2812596. [PubMed: 18177145].
- Gilavand A, Jamshidnezhad A. The effect of noise in educational institutions on learning and academic achievement of elementary students in Ahvaz, South-West of Iran. *International Journal of Pediatrics*. 2016; 4(3):1453-63. doi: 10.22038/IJP.2016.6500.
- de Souza TB, Alberto KC, Barbosa SA. Evaluation of noise pollution related to human perception in a university campus in Brazil. *Applied Acoustics*. 2020;157:107023. doi: 10.1016/j.apacoust.2019.107023.
- Connolly D, Dockrell J, Shield B, Conetta R, Mydlarz C, Cox T. The effects of classroom noise on the reading comprehension of adolescents. *J Acoust Soc Am*. 2019;145(1):372-81. doi: 10.1121/1.5087126. [PubMed: 30710912].
- Stansfeld S, Clark C. Health effects of noise exposure in children. *Curr Environ Health Rep*. 2015; 2(2):171-8. doi: 10.1007/s40572-015-0044-1. [PubMed: 26231366].
- Shield B, Dockrell JE. External and internal noise surveys of London primary schools. *J Acoust Soc Am*. 2004; 115(2):730-8. doi: 10.1121/1.1635837. [PubMed: 15000185].
- Forns J, Dadvand P, Foraster M, Alvarez-Pedrerol M, Rivas I, López-Vicente M, et al. Traffic-related air pollution, noise at school, and behavioral problems in Barcelona schoolchildren: a cross-sectional study. *Environ Health Perspect*. 2015; 124(4):529-35. doi: 10.1289/ehp.1409449. [PubMed: 26241036]; [PubMed Central: PMC4829987].
- Guski R, Schreckenber D, Schuemer R. WHO Environmental Noise Guidelines for the European Region: A Systematic Review on Environmental Noise and Annoyance. *Int J Environ Res Public Health*. 2017; 14(12):1539. doi:10.3390/ijerph14121539. [PubMed: 29292769]; [PubMed Central: PMC5750957].
- Zannin PHT, Marcon CR. Objective and subjective evaluation of the acoustic comfort in classrooms. *Appl Ergon*. 2007;38(5):675-80. doi: 10.1016/j.apergo.2006.10.001. [PubMed: 17202022].
- Soussi C., Larbi W., Deü JF. (2019) Experimental and Numerical Analysis of Sound Transmission Loss Through Double Glazing Windows. In: Fakhfakh T., Karra C., Bouaziz S., Chaari F., Haddar M. (eds) Advances in Acoustics and Vibration II. ICAV 2018. Applied Condition Monitoring, vol 13. Springer, Cham. doi: 10.1007/978-3-319-94616-0_20.
- Miskinis K, Dikavicius V, Bliudzius R, Banionis K. Comparison of sound insulation of windows with double glass units. *Applied Acoustics*. 2015; 92:42-6. doi: 10.1016/j.apacoust.2015.01.007.
- Kaiser OE, Pietrzko SJ, Morari M. Feedback control of sound transmission through a double glazed window. *Journal of Sound and Vibration*. 2003; 263(4):775-95. doi:10.1016/s0022-460x(02)01259-2.
- Tadeu AJ, Mateus DM. Sound transmission through single, double and triple glazing. *Experimental*

- evaluation. *Applied Acoustics*. 2001;**62**(3):307-25. doi:10.1016/S0003-682X(00)00032-3.
17. Ye L, Posada A, Liu Y. A Review on the Relationship between Chinese Adolescents' Stress and Academic Achievement. *New Dir Child Adolesc Dev*. 2019;**163**: 81-95. doi: 10.1002/cad.20265.[PubMed: 30614631].
 18. Crego A, Carrillo-Diaz M, Armfield JM, Romero M. Stress and academic performance in dental students: the role of coping strategies and examination-related self-efficacy. *J Dent Educ*. 2016;**80**(2):165-172.doi:10.1002/j.0022-0337.2016.80.2.tb06072.x.[PubMed: 26834134].
 19. Evans GW. The built environment and mental health. *Journal of urban health*. 2003;**80**(4):536-55.doi. 10.1093/jurban/jtg063. [PubMed: 14709704]
 20. Najafi N, Movahed K, Barzegar Z, Samani S. Environmental Factors Affecting Students' Stress in the Educational Environment: A Case Study of Shiraz Schools. *Int J School Health*. 2018; **5**(2): 1-7. doi: 10.5812/intjsh.67153.
 21. Wallas A, Eriksson C, Gruzieva O, Lind T, Pyko A, Sjöström M, et al. Road traffic noise and determinants of saliva cortisol levels among adolescents. *Int J Hyg Environ Health*. 2018; **221**(2):276-82.doi.10.1016/j.ijheh.2017.11.003. [PubMed: 29233481].
 22. Wålinger R, Gunnarsson K, Runeson R, Smedje G. Physiological and psychological stress reactions in relation to classroom noise. *Scand J Work Environ Health*. 2007; **33**(4):260-6.doi. 10.5271/sjweh.1141. [PubMed: 17717617].
 23. Talaiekhosravi A, Entezami A, Alebrahim A, Ziaee GR, Amani AM. Evaluation of noise pollution in Shiraz in 2018. *Journal of Air Pollution and Health*. 2018;**3**(4):199-208.doi: 10.18502/japh.v3i4.403.
 24. Cohen S, Kamarck T, Mermelstein R. A global measure of perceived stress. *J Health Soc Behav*. 1983; **24**(4): 385-96. doi: 10.2307/2136404. [PubMed: 6668417].
 25. Maroufizadeh S, Foroudifard F, Navid B, Ezabadi Z, Sobati B, Omani-Samani R. The Perceived Stress Scale (PSS-10) in women experiencing infertility: A reliability and validity study. *Middle East Fertility Society Journal*. 2018;**23**(4):456-9.doi: 10.1016/j.mefs.2018.02.003.
 26. Sigari N. Reliability and validity of Persian version of perceived stress scale (PSS-10) in adults with asthma. *Arch Iran Med*. 2014; **17**(5):361.[PubMed: 24784866].
 27. Berglund B, Lindvall T, Schwela DH. New WHO guidelines for community noise. noise & vibration worldwide. 2000;**31**(4):24-9 .doi.10.1260/0957456001497535.
 28. Rosenberg GG, Blake-Rahter P, Heavner J, Allen L, Redmond BM, Phillips J, et al. Improving Classroom Acoustics (ICA): A three-year FM sound field classroom amplification study. *Journal of Educational Audiology*. 1999; **7**:8-28.