Original Article

Acoustical comfort in the perception of literate school children

Conforto acústico na percepção de escolares alfabetizados

Juliana Feitosa dos Santos[1], Lilian Seligman[1], Tania Maria Tochetto[1]

ABSTRACT

Purpose: To verify the acoustic comfort of literate Primary School children. **Methods:** Participants were 82 children ranging from 8 to 10 years of age, in their third and fourth year of four public Primary Schools in the city of Santa Maria (RS), Brazil. The sample was divided into two groups – exposed and not exposed to sound levels over 80 dB(A). Visual inspection of the external auditory canal, pure-tone audiometry thresholds, speech recognition tests and acoustic immittance measures were used to select the sample. A Likert scale model questionnaire was applied in order to research the level of acoustic comfort. We also performed acoustic measurements in the classrooms using a dosimeter. Statistical analysis were conducted. **Results:** The mean acoustic level in each classroom varied from 51.9 dB(A) to 114 dB(A). From the total sample of 82 children, 20.7% were exposed to sound levels greater than 80 dB(A). Discomfort was referred by 46.3% of the total sample, hitting its highest level (51.3%) on the question of whether or not noise disturbs reading and writing processes. The attitude of comfort was predominant regarding speech intelligibility. As for reading and writing difficulties, discomfort was mostly indicated among subjects. **Conclusion:** The feeling of discomfort was predominant in both groups.

Keywords: Acoustics; School health; Noise; Auditory perception; Speech intelligibility

INTRODUCTION

Acoustic comfort refers to the limits in decibels that must be respected in order to preserve the auditory health, making the environment acoustically appropriate and agreeable to the individual. It is about a sensation of welfare, emotional tranquility that is characterized by the absence of unwanted sounds or the performance of acoustic activities that do not bother themselves or others, required in environments destined for rest or intellectual work[1-3]. Sensation of welfare may be considered an attitude, in other words, a way to act before something and in this particular case, the unwanted sound.

The *Conselho Nacional do Meio Ambiente* (CONAMA) nº 001, according to the resolution that mentions the regulating norm NBR 10.152/2000, establishes as maximum acceptable level for the acoustic comfort in classrooms values between 40 and 50 dB(A)[4]. Studies have shown that the maximum sound pressure level allowed inside classrooms (35 dB), recommended by the American National Standards Institute (ANSI), has been routinely exceeded in educational environments[5,6].

Considering the normal level of speech in the classroom at 65 dB(A), the ideal in speech/noise (S/R) signal ratio would be a quiet room (40 dB(A)) to maintain a difference greater than 10 dB for people with normal hearing and at least 15 to 25 dB for children with hearing impairment. When the noise increases, this difference decreases and the speech intelligibility becomes impaired, making it necessary for the teacher to increase the intensity of the voice to offset this disadvantage[7]. Another study indicates an ideal S/N ratio of 30 dB, but it found in public schools' classrooms a ratio below 12 dB[8].

High sound pressure levels arise from external sources, generated by vehicle traffic, aircraft and facilities near the school; places surrounding the classroom, such as, sports court and patio; and finally, internal sources, which correspond to noise generated inside the room as the conversation of the students, the sound of furniture or electrical equipment[7-9].

It is known that the effects of high noise levels are higher in children, and in this stage the activities are generally noisy, thus, this susceptibility increases[10].

The lack of urban and architectural planning has been commonly used as a justification for teaching activities do not occur in suitable acoustic conditions, whether by the uncontrolled growth of urban areas around the schools or lack of development of constructions with rigid acoustic criteria. The application of specific constructs that can improve the sound transmission and the reverberation control is commonly suggested[10,11].

Study conducted at the Graduate Program in Human Communication Disorders, Universidade Federal de Santa Maria – UFSM – Santa Maria (RS), Brazil.
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(1) Graduate Program in Human Communication Disorders, Universidade Federal de Santa Maria – UFSM – Santa Maria (RS), Brazil.
Correspondence address: Juliana Feitosa dos Santos. Av. Esperança, 1416, Manaíra, João Pessoa (PB), Brasil, CEP: 58038-281. E-mail: fgajulianasantos@gmail.com
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The literature shows that high sound pressure levels in the classroom interfere in the child's learning, impairing attention and concentration, besides hindering proper communication between teacher and student. The necessity of repeating the message, annoys, confuses and tires the speaker and the listener, interfering with auditory discrimination and reading. This difficulty may be aggravated if there are subjects with hearing disorders, even of mild degree[12-15]. Thus, the intelligibility of speech conceptualized by the relation between spoken words and understood words becomes jeopardized. The level of speech, the reverberation of the room and the background noise are factors that participate in the hearing process. The maturation degree of the central auditory system, the acoustic experience, the position of the listener, the sounds reflected, the age of acquisition of phonemes and any difficulties in reading and writing interfere with speech intelligibility[11,16-18].

Given the above, the purpose of this research was to analyze the acoustic comfort of literate students in four public schools from Santa Maria (RS), Brazil.

METHODS

This research was approved on ethical and methodological aspects by the Research Ethics Committee of Universidade Federal de Santa Maria, and the case number is 23081.020148/2010-93 CAAE (*Certificado de Apresentação para Apreciação Ética*) 0371.0.243.000-10.

All legal guardians of the subjects involved in the study signed a consent term. A term of assent was signed by the child and a term of authorization was signed by the directors of educational institutions.

The nature of the study is quantitative and qualitative. As to the object, it is a field study, having as technique the direct documentation, using questionnaires and tests. Considering the objectives, it is combined exploratory-descriptive, and deductive with regard to the method.

For the selection of the sample, subjects were evaluated by visual inspection of the external auditory canal; pure-tone audiometry (air conduction), speech recognition threshold (SRT) and percentage of speech recognition index (SRI) with use of disyllabic and monosyllabic words, respectively, by speakerphone with audiometer, Madsen-GN Otometrics®, Itera, type II, with phones TDH-39, tympanometry and research of the stapedial reflex thresholds using acoustic impedanciometer Interacoustics®, AZ 26.

Exclusion criteria of the sample involved the unavailability of parents, children and educators to collaborate with the research, the presence of learning and speech disorders, neurological alterations, sensorineural hearing loss with thresholds worse than 25 dB; LRF non-compatible with the pure-tone audiometry and SDT lower than 88%. Were excluded from this study six children with thresholds higher than set forth above, one child for signs of neurological changes, six by forfeit and another one by school transfer.

Therefore, after the exclusion mentioned above, the sample consisted of 82 children of both genders, with 43 females (52.4%) and 39 males (47.6%), aged 8-10 years, students of third and fourth grades of elementary school from four public schools in Santa Maria.

Measurements of sound pressure levels were performed with the dosimeter Bruel & Kjaer® model 4445, adjusted for compensation scale A, linear, slow response speed, placed on the collar of a student with calm behavior positioned in the middle of the room. It was adopted a fold factor Q=5 dB for the exposure time and tolerance for noise at 85 dB, according to the criteria established by NR15. The conditions for each class were maintained on aspects of everyday life, such as windows and doors open or closed, fans on or off, teachers placed in their usual places and children in their usual activities.

The acoustic events measured in this study correspond to the Middle Level Sound (Lavg) and Maximum Sound Pressure Level (SPL max). We chose to use as cutoff criteria for the groups of the sample the sound pressure level of 80 dB(A) action level (level that considers preventive measures to minimize risks to the hearing exposed to high noise levels). For this, it is necessary to prevent the limit of 85 dB(A) to be exceeded[19]. However, this research also considered that such limit, based on the resolution of CONAMA, causes interference in human communication. Thus, the sample resulted in group of exposed (up to 80 dB(A)) and unexposed (as 80 dB(A)) in high sound pressure levels[4].

According to the criteria established for exposed and unexposed, the sample resulted in 17 (20.7%) exposed children and 65 (79.3%) not exposed. Regarding exposed children, we have: ten females and seven males. Of all children at age eight, 13 were exposed and 21 were not; of all nine-year-olds, 41 were exposed and four were not, besides three children aged ten who were not exposed. Since there was no difference between genders (p=0.59) and age (p=0.08) related to acoustic measurements, the sample was analyzed together.

We used a questionnaire based on the model sum scale of Likert, with statements related to environmental sound levels, which we call "noise" for better understanding of children. The Likert scale is an indirect measurement range of attitudes and comprises a series of statements or judgments, and before them is requested the reaction of the subject through the investigated object[20]. Respondents are asked to agree, disagree or remain neutral about the statements. These reactions are the categories used to infer about attitudes.

Attitude is an underlying predisposition of the person in determining their behavioral response relative to a product, organization, person, event or situation. Thus, attitudes are behavioral representations and not behaviors, are indicators of conduct and not conduct itself and are related to the behavior that we have around the objects to which we make references[21]. So attitudes are defined as a predisposition to answer consistently in a favorable or unfavorable way, compared to an object and its symbols. They have several properties, such as the direction (positive or negative) and intensity (high or low) to a given event[22].

In this study, we opted for the establishment of five statements: 1. The noise disturbs me in the classroom 2. I misunderstand what the teacher says when there is noise 3. My school is noisy 4. I find it difficult to read or write when the room is noisy, 5. I lose the will to pay attention in class

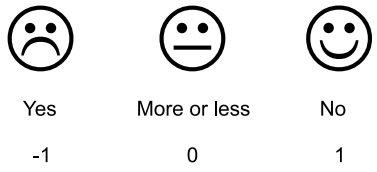

Figure 1. Categories of responses

when it is noisy. The possible answers were prepared in three categories, related to the feeling of comfort through the environmental sound pressure levels (noise). They were: yes (the noise bothers you), more or less (impartial) and not (it doesn't bother you). The scale was adapted with figures representing the response categories to better understanding of the research subjects[21,22].

Was assigned a number to each response, which are -1, 0 and 1. Therefore, the sum of the scores of the subject's responses to all items is understood as representative of their favorable/unfavorable or neutral position in relation to the phenomenon that is measured[20].

We used the nonparametric test chi-square and the Fisher exact test, with significance level set at 5% ($p \leq 0.05$) for the analyzes.

RESULTS

As for the noise measurements, it was observed difference ($p<0.001$) between the sound pressure levels measured in each school (Table 1).

The record of sound pressure levels scaled by Lavg (average) per classroom (M=71.44, SD=10.2) ranged between 51.9 dB(A) and 114 dB(A) (Table 1).

The maximum sound pressure levels showed a high level, especially in room 3 with NPSmax=114 dB(A). The lowest value was found in room 10, being equally harmful with NPSmax=87.2 dB(A) (Table 1).

The results for the acoustic comfort, obtained through the categories selected in Likert questionnaire, are presented in Table 2.

It may be seen that two of the five statements showed superiority in the percentage of discomfort with the "yes" response among those exposed. Thus, in the categories "noise disturbs" and "difficult to read or write in noise," prevailed discomfort (Table 2).

With regard to the statement "difficult to read or write in noise," there was a predominance of children who feel harmed in both skills (51.23%). Of these 42 children, eight (9.8%) mentioned that reading difficulty is most evident, and four (4.9%), in turn, refer to writing as an aspect noticeably impaired. This category showed the highest percentage of discomfort in the study.

Table 1. Sound pressure levels measured in classrooms

Environment	Lavg	NPS Max
Classroom 1	80.9	99.1
Classroom 2	65.2	92.1
Classroom 3	114	114.0
Classroom 4	63.7	93.2
Classroom 5	81.3	96.0
Classroom 6	70.2	92.5
Classroom 7	74.6	93
Classroom 8	63.1	88.3
Classroom 9	72.8	95.1
Classroom 10	51.9	87.2
p-value	0.001*	-

Chi-square test ($p \leq 0.05$)
Note: Lavg = average sound; NPS Max = maximum sound pressure level

As for acoustic comfort, the results showed no difference between male and female gender (p=0.837).

Comparing the acoustic measurements and the attitudes of respondents for each statement, it was observed that there was no difference between groups of exposed and unexposed children and the acoustic comfort degree that was investigated (p=0.89) (Table 3).

The results reported in Chart 1 show that the attitudes occupy negative positions in greater number, so they indicate discomfort for both exposed and unexposed to noise. Individuals who have demonstrated an attitude of impartiality to the degree of comfort, choosing the category "more or less" resulted in percentages of 17.65% and 15.38% respondents, respectively.

DISCUSSION

Given the acoustic measurements performed and from the analyzes, is prominent to consider that 100% of schools and classrooms in this study exceeded the acceptable sound pressure levels, which are imposed as maximum, of 40 to 50 dB(A) to classrooms[4].

The data suggested, therefore, that all children in the study are exposed to sound pressure levels able to cause school disor-

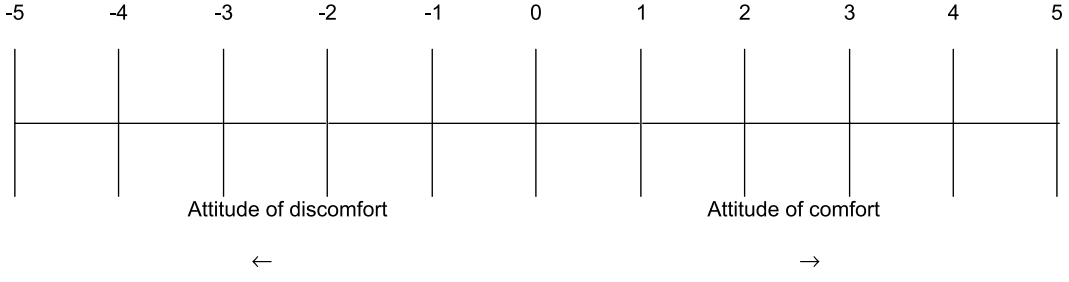

Figure 2. Likert scale – Scoring the algebraic sum

Table 2. Statements related to environmental noise

Affirmative	Groups	Responses (n=82)			p-value
		Yes (%)	More or less (%)	No (%)	
The noise disturbs me in the classroom	Exposed	13.41	4.88	2.44	0.23
	Not exposed	32.93	30.49	15.85	
I misunderstand what the teacher says when there is noise	Exposed	6.1	7.32	7.32	0.14
	Not exposed	12.20	48.78	18.28	
My school is noisy	Exposed	7.32	2.44	10.98	0.13
	Not exposed	40.24	17.07	21.95	
I find it difficult to read or write when the room is noisy	Exposed	10.98	2.43	7.32	0.51
	Not exposed	40.25	18.29	20.73	
I lose the will to pay attention in class when it is noisy	Exposed	3.66	4.88	12.2	0.99
	Not exposed	14.63	19.51	45.12	

Chi-square test ($p \leq 0.05$)

Table 3. Relation between attitudes and environmental noise

Groups (n=82)	Comfort n (%)	p-value	Impartiality n (%)	Discomfort n (%)
Exposed	5 (6.1)	0.89	3 (3.66)	9 (10.97)
Not exposed	22 (26.83)		10 (12.20)	33 (40.24)
Total	27 (32.93)		13 (15.86)	42 (51.21)

Chi-square test ($p \leq 0.05$)

Chart 1. Distribution of noise levels and attitudes of the children studied, applied to the Likert scale

Group	Concordance nuisance to NPS						Mismatch nuisance to NPS				
	Discomfort					Impartiality	Comfort				
	-5	-4	-3	-2	-1	0	1	2	3	4	5
Exposed (n=17)	-	-	5.88%	17.65%	29.41%	17.65%	-	17.65%	5.88%	-	5.88%
	Total (percentage) – 52.94% ←					17.65%	→Total (percentage) – 29.41%				
	-5	-4	-3	-2	-1	0	1	2	3	4	5
Not exposed (n=65)	-	1.54%	16.92%	13.85%	18.46%	15.38%	10.77%	6.15%	13.85%	1.54%	1.54%
	Total (percentage) – 50.77% ←					15.38%	→Total (percentage) – 33.85%				

Note: NPS = sound pressure level

ders, such as lack of attention, reading and writing difficulties and loss of speech intelligibility[6,12,13].

Of all children in this study, 20.7% were in the group exposed to noise with sound patterns similar to those identified in a research conducted at Distrito Federal, where the sound levels in classrooms ranged between 81.4 and 84.7 dB(A), indicating inadequate school environments and possible damage to hearing and learning[6].

These losses lead to the precept that one must know the needs of the school environment in order to promote awareness and good health behaviors, thus justifying the relevance of this research in which were analyzed children's attitudes through the presence of noise in their locus[23].

Correlating the acoustic measurements and the attitudes of the students, it was observed superiority of the number of children who feel uncomfortable with the noise in the classroom (51.21%), being exposed to high sound pressure levels or not. This condition reflects the perception and annoyance caused by noise, because its presence is undesirable in both situations, regardless of their aggressive ability to hearing. In a study carried out in private schools in Curitiba it was investigated the perception of 80 children about the noise. Among the negative aspects reported in the classroom, the noise was the most reported in a score of 76.25% among respondents. The authors concluded that the hearing sensitivity of students is a clear demonstration of annoyance with the noise, which can cause damage to learning[12]. This study corroborates the findings of this survey, which showed that the school is considered noisy by 47.56% of the children.

Referring to the understanding of the teacher's speech, there was a predominance of the answer "more or less" (56%). Impartiality can demonstrate indifference to noise or that the difficulty arises as the time, or under the influence of educational activities provided.

Consider that a teacher keeps a speech level of 65 dB. To maintain a proper S/N ratio it would be necessary to speak 10

dB above the sound pressure levels present in the classroom[7]. Therefore, we observe that in this study, using as criteria the values found by Lavg, teachers would need to raise his voice between 80 dB and 124 dB, which would be impractical. The speech intelligibility can be reduced the greater the distance between the speaker and listener[10], however, the different positions of each student in the classroom were not considered in this research, which could show greater losses.

Among the measures of environmental comfort (temperature, noise and lighting) rated in municipal schools of João Pessoa, most of the tests exceeded the levels required by NBR 10.152/ABNT. Among the considered aspects, the noise has emerged as the main discomfort reported by teachers, interfering directly in the activities in the classroom[15]. These data complement the findings of this study, since in this study the students were the ones who showed the noise as a cause of discomfort in the classroom.

In order to compare the perception of daily urban noise of the inhabitants of two distinct areas of a city, a study showed that sensitivity to increased noise is noticeable, alternating the speech of the participants between "increased" and "greatly increased" with ease.

The physiological effects of higher occurrence in the study were irritability and poor concentration[24], supporting the findings of this research. In this study, we found that the highest percentage of discomfort was related to reading and writing, in which we can infer the lack of concentration. The European project entitled "Road traffic & aircraft noise & children's cognition & health" has shown that exposure to noise levels exceeding 55 dB due to aircraft overflight, impairs reading and memory of the children[14]. Research that analyzed the effects of irrelevant sounds confirmed that even when instructed to ignore the sounds, the children are negatively affected in the performance of memory, a function required so that the reading becomes effective[25].

Of the four analyzed schools, three are in the noise area caused by aircrafts. Specifically, the third room, which had average Lavg=114 dB(A), located near the landing track. When there is chronic exposure to aircraft noise, the impact on quality of life is most apparent in children by their own vulnerability to this type of noise. It may also result in poor cognitive performance, changes in welfare and low motivation in school[9].

Regarding the motivation to pay attention in class, 57.3% of children said they did not feel disadvantaged in this respect, contrary to what was said regarding the noise nuisance. Such an attitude suggests that, although the noise bothers, children adopt an attitude of compliance with the situation, or nuisance is not strong enough to change their motivation for participation in the classroom. Children represent a group of individuals vulnerable to non-auditory effects of noise on health. They have less capacity to anticipate stressors and to use of strategies that focus on the information[26].

The individual susceptibility referred since the 80s[27], should be considered because there are people more or less tolerant to noise. However, this factor only minimizes the hassle, but does not protect the individual from the consequences of exposure to which it is submitted.

From this perspective, the Likert scale data showed that discomfort was predominant in both groups, but showed no difference between exposed and unexposed (Table 1).

Relaxation exercises made with the students help to reduce the noise caused by their own activities and increase the concentration, while considering that the control of the functional aspects of the classroom keeps the environment healthy and should not be discarded[28].

It is essential to control the measurement of sound pressure levels and tolerance limits that shape the hearing loss prevention and environmental discomfort. The school as a social institution carries on its core basic conditions to develop an outreach work of the problems caused by noise. Thus, brings out its performance as an agent of spreading scientific knowledge, that presents itself as an object of analysis, which generates knowledge based on the theory and practice, that is, learning by doing[23]. This last consideration leads the professionals involved in preserving the health of the child to reflect on ways to intervene in the school environment to hear complaints and demands that require action and awareness for the modification of the environment.

CONCLUSION

Based on the results it is concluded that the noise is a unwanted factor that causes discomfort in young children both exposed and not exposed to high sound pressure levels.

RESUMO

Objetivo: Verificar o conforto acústico de alunos alfabetizados. **Métodos:** Participaram da pesquisa 82 crianças, de 8 a 10 anos, alunos do terceiro e do quarto ano do Ensino Fundamental, de quatro escolas municipais de Santa Maria. Dividiu-se a amostra em dois grupos – expostos e não expostos a níveis maiores que 80 dB(A). Para a seleção da amostra realizou-se inspeção visual do meato acústico externo, audiometria tonal e vocal e timpanometria. Para a pesquisa do conforto acústico foi aplicado um questionário baseado no modelo de escala somatória Likert, com a finalidade de avaliar as atitudes em relação ao conforto acústico. Foram executadas mensurações acústicas nas salas de aula, por meio de dosímetro. Os resultados foram analisados estatisticamente. **Resultados:** O nível sonoro médio obtido por sala de aula variou de 51,9 dB(A) à 114 dB(A). Do total de 82 crianças, 20,7% estavam expostas a níveis mais elevados que 80 dB(A). O desconforto relatado pelas crianças apresentou um percentual de 46,3% dentre o grupo total. O maior percentual de desconforto (51,23%) foi verificado para a afirmativa que investiga se o barulho atrapalha a leitura e a escrita. Em relação à inteligibilidade de fala, prevaleceu a atitude de conforto. Quanto à dificuldade na leitura e escrita, foi verificado o maior percentual de desconforto indicado entre os respondentes. **Conclusão:** A sensação de desconforto predominou em ambos os grupos estudados.

Descritores: Acústica; Saúde escolar; Ruído; Percepção auditiva; Fala

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