

# THE INFLUENCE OF NOISE ON VERBAL AUDITORY TEMPORAL ORDERING ABILITY

## *A influência do ruído na habilidade auditiva de ordenação temporal para sons verbais*

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### ABSTRACT

**Purpose:** to investigate the relationship between the background noise level in classrooms and the auditory temporal ordering ability for verbal sounds. **Methods:** a descriptive cross-sectional study of a sample of 209 students aged seven to ten years. Noise assessment was performed in 13 classrooms at eight public schools in Belo Horizonte. The procedure was based on the measurement of the acoustic parameter named equivalent sound pressure level considering empty and furnished classrooms, according to the standard American National Standards Institute (ANSI) S12.60. To assess auditory temporal ordering ability for verbal sounds on students, verbal sequential memory test. For statistical analysis, noise has been categorized by the median value and related to student achievement on the test. **Results:** with the test results, most students showed normal results and no difference was found related to sex and age. All classrooms had values above the recommended by international standards (ANSI S12.60 and Bulletin 93) and national (Brazilian Association of Technical Standards – NBR10152), which set up appropriate values. By relating the noise with student performance on the test, there were differences, with greater occurrence of changes in the students belonging to the noisiest rooms. **Conclusion:** the background noise level measured in classrooms are above of those permitted by the standards and there was no relationship between the background noise level in the classrooms and the level of difficulty in auditory temporal ordering ability.

**KEYWORDS:** School Health; Noise; Noise Effects; Auditory Perception; Hearing Tests; Learning

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### ■ INTRODUCTION

Learning is the means by which an individual is integrated into society. The learning process requires both cognitive skills and a favorable environment. It is the responsibility of governments to offer conditions—via schools—to further the various potentialities of students<sup>1</sup>.

The most important instrument for conveying knowledge in the school setting is the teacher's voice<sup>2</sup>. In addition to having physiologically adequate hearing according to parameters of normality, students are required to interpret and recognize the verbal message transmitted in order to understand it<sup>3</sup>. Auditory abilities, also known as "auditory processing", are among the key capabilities in learning. These abilities are related to how

individuals interpret what they hear. Auditory abilities comprise the set of skills involved in sound localization and lateralization, auditory discrimination, auditory pattern recognition, temporal aspects of hearing, and auditory performance in the presence of competing and degraded acoustic signals<sup>4</sup>. These skills are constantly used by individuals without auditory impairment in communication settings.

Among the auditory processing abilities, temporal aspects play a central role in speech comprehension and, consequently, in the development of language<sup>5,6</sup>. Temporal processing encompasses the abilities of temporal ordering (or sequencing), integration (or summation), masking, and resolution (or temporal acuity)<sup>6</sup>. These abilities enable the perception of sound alterations in time and space<sup>6</sup>. In the present study, we evaluated verbal auditory temporal ordering ability, understood as an individual's ability to perceive different stimuli in their sequence in time<sup>6</sup>.

For adequate processing of sounds, the acoustic signal must reach the listener effectively. This requires an acoustically favorable environment. A favorable environment is critical to speech intelligibility, which is determined by the relationship between the words uttered and the words understood. One of the factors that compromise speech intelligibility is school ambient noise<sup>7</sup>.

In the classroom, background noise is a detrimental factor to effective teacher-student communication, since it competes with the teacher's speech<sup>2,7,8</sup> and leads to poorer perception and interpretation of sounds<sup>9</sup>.

Numerous studies have been conducted to measure the impact of ambient noise on auditory skills in the school environment<sup>10-12</sup>. There is a body of evidence demonstrating the interference of noise in students' auditory skills, which are necessary to effective comprehension of curricular content<sup>11,13</sup>. It has also been demonstrated that adequate acoustics is lacking in schools<sup>14</sup>.

Academic success is not the sole responsibility of the education sector. Rather, it involves the whole of society, which should have education as a solid foundation through the exercise of shared accountability and management. In the present days, policy-makers have been concerned with students' learning, as reflected in the increased investments on policies aimed at integrating health and education. The school health program is geared toward fostering a climate of prevention and health promotion initiatives to minimize negative impacts on education and health—as in the case of noise—by means of educational programs<sup>1</sup>.

Considering the present status of schools and the importance of good performance of auditory

abilities for effective learning, the aim of the present study was to investigate the relationship between classroom noise and the auditory ability of temporal ordering for verbal sounds in the teaching-learning setting.

## ■ METHODS

The present cross-sectional descriptive study involved a convenience sample of eight public schools in Belo Horizonte and was approved by the Universidade Federal de Minas Gerais Research Ethics Committee under protocol 352/2012.

The schools were selected with a view to including a variety of building characteristics and regions of the city as well as different traffic conditions in order to encompass the most diversity of exposure to noise. In each of the schools, two classrooms were randomly selected for an acoustic assessment. In one school, only one classroom could be evaluated. In all, 13 classrooms participated in the study.

The sample comprised 209 children aged 7–10 years, with 108 boys and 101 girls (48.3%).

All the students were regularly enrolled in the elementary classes of the schools under study, which was the eligibility criterion for participation. The exclusion criteria were the presence of attention deficits, auditory or motor impairment as identified by the teacher, uncooperative students, or difficulties in performing the test.

In addition to evaluating the students, we measured the noise level in the 13 classrooms and analyzed the acoustic parameter of equivalent sound pressure level (Leq).

The children's parents were informed that participation in the study was voluntary; they were also informed about the study aims and repercussion. Subsequently, the parents provided their written informed consent.

The boards of the participating schools were clarified with regard to the study and authorized the noise level measurements in the classrooms as well as the tests to be conducted with the children.

Equivalent sound pressure levels were measured using an Instrutherm digital sound pressure level meter model DEC-490 with a data-logger and a type 2 microphone. The measurements were performed by a trained professional over the frequency range of 63Hz to 8 KHz at 1 s intervals between measurements, with the classrooms unoccupied, furnished, and with usual class activities being developed in the adjoining classrooms. Data were collected during 1 h. The sound pressure level meter was positioned at 1.20 m from the floor, 0.5 m from mobile objects and at 1 m from the walls and fixtures. The back of the classroom, near the window, was the chosen

site because it was considered the worst case or noisiest location in the room. The measurements were based on the international regulations of the Acoustical Society of America – ANSI S12.60 (2010)<sup>15</sup>.

The auditory ability of temporal ordering for verbal sounds was evaluated using the verbal sequential memory test administered by trained investigators. Testing consisted of repetitions of the syllables PA, TA, KA, and FA in varying sequences<sup>16,17</sup>. The test is standardized for individual administration. However, we adapted it for group testing to simulate a real-life context of teaching and learning. The syllables were recorded in an acoustically treated laboratory by a female speaker using the Audacity software. The test was played back at 65 dB(A) to represent the teacher's voice in a classroom without vocal strain<sup>18</sup>.

The students received a form containing graphic sequences of the syllables PA, TA, KA, and FA, and were instructed to mark an "X" on the sequence they heard from fixed sets with three answer choices<sup>16,17</sup>. The test criteria for analysis and interpretation establish that marking the correct answer in at least two sequences of four syllables in three presentations represents normality<sup>16,17</sup>.

The data were analyzed using the SPSS 16.0 software. We conducted descriptive statistics of the categorical variables and measures of central tendency and dispersion of the continuous variables.

To analyze the relationship between student performance in the verbal sequential memory test and classroom equivalent sound pressure levels, the  $L_{eq}$  variable was categorized on the basis of the median value of 60 dB(A). Thus, the classrooms were divided into two categories: a) classrooms with a mean noise level  $\leq 60$  dB(A) and b) classrooms with a noise level  $> 60$  dB(A).

We used the  $X^2$  test and Student's  $t$  test to analyze the association of the temporal ordering test results with the variables sex, age, and  $L_{eq}$ .

## ■ RESULTS

We evaluated 229 students and excluded 20 of these based on the exclusion criteria. Therefore, the final sample comprised 209 students, with a mean age of 8 years and 7 months (SD = 0.96).

Most students achieved normal results in verbal temporal ordering (Table 1).

**Table 1 – Results of the verbal temporal ordering test of 209 students by age group**

Age group (years)	Altered		Normal		Total		Mean of correct answers	SD
	N	%	n	%	n	%		
7	3	1.43	17	8.13	20	100	1.85	0.36
8	15	7.17	58	27.75	73	100	1.79	0.40
9	16	7.65	44	21.05	60	100	1.73	0.44
10	8	3.82	48	22.96	56	100	1.85	0.35
Total	42	21	167	79	209	100	1.80	0.40

Note: N = number of subjects; SD = standard deviation  
Descriptive Analysis: Frequency and Dispersion

No statistically significant difference was found when the results of the temporal ordering test were compared relative to sex and age ( $p > 0.05$ ) (Table 2).

The values of  $L_{eq}$  in the assessed classrooms ranged from 54.9 to 70.37dB (A), with a mean of 62.4 dB(A) (SD = 4.6) (Figure 1).

We found an association between noise levels and the test of temporal ordering for verbal sounds, since 70.6% of the students who had below-normal results were in classrooms with a noise level  $> 60$  dB(A) (Table 3).

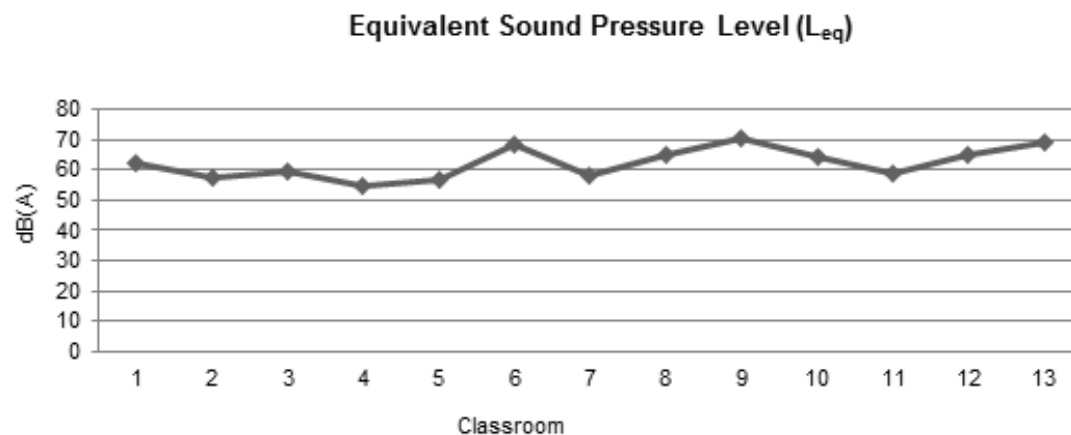
Table 2 – Results of the temporal ordering test by sex and age

Variables	Temporal ordering test		P-value	
	Altered (n=42)	Normal (n=167)		
Sex	M	17	84	0.25*
	F	25	83	
Age	Mean (SD)	8.69 (0.86)	8.74 (0.98)	0.78**

\*Nonsignificant ( $P > 0.05$ ) –  $\chi^2$  test

\*\*Nonsignificant ( $P > 0.05$ ) – Students  $t$  test

Note: N = number of subjects; SD = standard deviation



Note: dB(A) = decibels at hearing level

Figure 1 – Variation of the equivalent sound pressure level in 13 classrooms

Table 3 – Relationship between  $L_{eq}$  values and temporal ordering test results

Equivalent Sound Pressure Level ( $L_{eq}$ )	Students with altered results		Students with normal results		P-value
	N	%	n	%	
Moderate ( $\leq 60$ dB)	12	28.6	83	49.7	0.01
Elevated ( $> 60$ dB)	30	71.4%	84	50.3	
Total	42	21%	167	79%	

\*Values with statistical significance ( $P < 0.05$ ) –  $\chi^2$  test

Note: N = number of subjects

## ■ DISCUSSION

The students were evaluated with regard to the  $L_{eq}$  variable and classified into two categories. They were also evaluated regarding their performance in the verbal temporal ordering test. Because there is no dichotic listening test standardized and validated for the Brazilian context, we chose to adapt the verbal sequential memory test to be used with a group in order to simulate an actual teaching-learning situation in the classroom setting.

Considering that the literature reports 65 dB as the vocal intensity of teachers in that setting<sup>18,19</sup>, the test was recorded and played back at 65dB. There are reports in the literature indicating that higher levels of vocal production cause symptoms of vocal fatigue, a burning sensation in the throat, vocal strain, and, over time, laryngeal alterations<sup>8</sup>.

We found no difference in the results of the verbal temporal ordering test for the variables sex and age (Table 1). This finding diverges from the literature, as some studies show boys performing

better in tests assessing auditory processing in school age children<sup>11</sup>. Moreover, previous studies showed improved performance with increasing age, which can be explained by the neuromaturation process<sup>9,20</sup>.

The results of the temporal ordering test were outside of the normal range for some students. Other studies found similar numbers of such alterations<sup>21,22</sup>. Therefore, those students had problems with their verbal auditory temporal ordering ability, which warrants the investigation of the integrity of auditory processing in schoolchildren. Given that a large proportion of the information discussed in the classroom is presented verbally by the teacher and the other students, a deficit in auditory processing could lead to speech comprehension and learning difficulties and thus contribute to a student's academic failure.

The literature also points to a relationship between learning deficits and poorer outcomes in the verbal sequential memory test<sup>21,22</sup>. In the teaching-learning process, children should perceive the content conveyed by the teacher's speech, which requires adequate information processing<sup>23</sup>. After a student detects a sound using peripheral hearing, several central nervous system organs act in concert to decode the message. Studies have shown that enhancing auditory skills leads to a significant improvement in school performance<sup>24</sup>.

In the schools where the  $L_{eq}$  was measured, all classrooms showed levels exceeding those deemed acceptable by the regulations of the ANSI S12.60 (2010), Building Bulletin 93 (2004), and the Brazilian Association of Technical Standards (*Associação Brasileira de Normas Técnicas*—ABNT) — NBR 10152 (2012), which recommend an upper limit of 35 dB(A) for unoccupied classrooms<sup>15,25,26</sup>. The same problem was observed in national<sup>8,27</sup> and international<sup>14,28,29</sup> studies, which noted that, even during school recess, the classrooms failed to meet the requirements established by the regulations<sup>17,28,29</sup>. Equivalent sound pressure levels were elevated even in unoccupied classrooms. These facts point to inadequate planning regarding the acoustic comfort of classrooms<sup>2,19</sup>. The design of school buildings should prioritize adequate school acoustics, as prolonged exposure to noise can be harmful to health and have a negative impact on teaching and learning<sup>2,8,23</sup>.

In compliance with the established guidelines, noise levels were measured in unoccupied classrooms. However, noise produced within the classroom is known to have a strong impact on the teaching-learning dynamic and is one of the noise sources most frequently reported by teachers<sup>11</sup>.

Most of the students who showed deficits in the verbal sequential memory test have classes in the classrooms with high  $L_{eq}$  values. This fact supports the hypothesis that noise is an influential factor on the results of dichotic listening tests in children with or without learning impairment<sup>13</sup>. A number of studies show the influence of noise on other auditory skills<sup>11</sup>. Those findings suggest the impact of noise on activities that demand auditory abilities for adequate speech comprehension, with a potentially detrimental impact on academic performance.

Educational initiatives concerning the influence of noise on learning and its harmful effects on health, combined with measures to attenuate noise in the school setting are paramount to creating environments conducive to school health<sup>2,19,27</sup>. Practices such as attaching rubber caps to the ends of the classroom chair and desk legs, adequate fan maintenance, and locating the playground and recreational areas away from the classrooms, as well as educational measures, could contribute to the attenuation of ambient noise levels<sup>2</sup>. Health and education professionals should both promote the creation of learning-friendly environments.

Schools investing in prevention and health promotion enhance the teaching-learning process<sup>1</sup>. From that perspective, the school speech-language pathologist and audiologist should intervene based on a holistic approach focused on student health<sup>30</sup>. The role of this professional extends beyond traditional clinical practice, as he or she has to be aware of the local reality and the determinants of health in the school population to support the implementation of policies to improve the school environment and the learning process. As a family medicine practitioner, the speech-language pathologist and audiologist—and the other health team members—should endeavor to bring health and education together with an emphasis on the students' health<sup>1</sup>.

## ■ CONCLUSION

Classroom noise levels exceeded those established by the regulations and affected student performance regarding the ability of verbal auditory temporal ordering.

Noise is a detrimental factor to the understanding of the teacher's speech by students and can interfere with their learning. It should be emphasized that health professionals and educators should be partners in creating health-promoting in school in order to attenuate the impact of factors that hinder successful learning.

**RESUMO**

**Objetivo:** apurar a relação entre o ruído presente em sala de aula e a habilidade auditiva de ordenação temporal para sons verbais. **Métodos:** estudo descritivo transversal, com amostra de 209 estudantes com idade entre sete e dez anos. Foi realizada a avaliação do ruído em 13 salas de aula de oito escolas públicas municipais de Belo Horizonte, por meio da medição do parâmetro acústico nível de pressão sonora equivalente, com as salas de aula vazias e mobiliadas, de acordo com a norma American National Standards Institute (ANSI) S12.60. Para avaliar a habilidade auditiva de ordenação temporal para sons verbais nos estudantes, foi utilizado o teste de memória sequencial verbal. Para fins de análise estatística, o ruído foi categorizado pelo valor da mediana e relacionado aos resultados dos estudantes no teste. **Resultados:** a maioria dos alunos apresentou resultado normal no teste e não houve diferença em relação ao gênero e à idade. Todas as salas de aula apresentaram valores de nível de pressão sonora equivalente acima do preconizado pelas normas regulamentadoras internacionais (ANSI S12.60 e Bulletin 93) e nacional (Associação Brasileira de Normas Técnicas –NBR10152). Ao relacionar o ruído com o desempenho dos alunos no teste, houve diferença, com maior ocorrência de alterações nos alunos pertencentes às salas mais ruidosas. **Conclusão:** os níveis de ruído mensurados nas salas de aula estão acima do permitido pelas normas e constatou-se relação entre ruído presente na sala de aula e maior dificuldade na habilidade auditiva de ordenação temporal.

**DESCRITORES:** Saúde Escolar; Ruído; Efeitos do Ruído; Percepção Auditiva; Testes Auditivos; Aprendizagem

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