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The effect of noise on attention and performance in reading and writing tasks

Interferência do ruído no foco atencional e no desempenho em testes de leitura e escrita

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Keywords

Attention
Handwriting
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ABSTRACT

Purpose: This study investigated the effects of two levels of noise on the performance of young students of three educational levels and tested their ability to maintain attentional focus in reading and writing tasks. **Methods:** 162 school children in the third, fourth and fifth grades were placed in three groups according to their educational level: Control Group (CG), Experimental Group A (GEA) and Experimental Group B (GEB). All groups were submitted to a Sustained Attention Test, Reading Assessment and Isolated Words Test and Writing Dictation Sub-test (part of the International Dyslexia Test). The GEA and GEB performed the tests in a noisy environment: 20dB and 40dB, respectively. The CG was assessed in the usual school environmental noise at the same time of the day. The data was submitted to an ANOVA, the Kruskal-Wallis test and Spearman correlation test. **Results:** The higher the score on the Sustained Attention Test, the shorter the time spent reading and fewer errors in the dictation task. There were no differences across the three grades within the GEA (lower levels of noise) with regard to the effect of noise on attention and in the reading and writing task performance. The higher levels of noise for the GEB, however, decreased the attention levels, therefore increasing mistakes on the dictation test. Comparing the performance across educational levels on the reading tasks, the fourth grade presented decreased reading time, while the third and fifth grades spent more time reading. **Conclusion:** Auditory interference can influence the ability to focus attention as well as worsen performance in reading and writing tasks at more intense noise levels.

Descritores

Atenção
Leitura
Escrita Manual
Aprendizagem
Ruído

RESUMO

Objetivo: Investigar os efeitos de dois níveis de ruído sobre tarefas de atenção e de escrita e leitura em estudantes de três níveis de escolaridade. **Método:** 162 sujeitos entre o 3º, 4º e 5º ano do Ensino Fundamental foram alocadas em três grupos conforme a escolaridade: controle (GC), experimental A (GEA) e experimental B (GEB). Todos os grupos foram submetidos aos testes de Atenção Concentrada de Cambraia; Avaliação de Leitura e Palavras Isoladas; Subteste Escrita sob Ditado do *International Dyslexia Test*. Os grupos GEA e GEB realizaram os testes em ambiente com ruídos de 20 dB e 40dB respectivamente. Os resultados foram analisados com teste de *Kruskal-Wallis* e correlação de *Spearman* com significância em 5%. **Resultados:** Foi observado que quanto maior o escore no teste de atenção, menor o tempo gasto na leitura e menor o número de erros no ditado. Não houve diferenças nos três anos de escolaridade para o grupo GEA quanto à influência do ruído sobre a atenção e o desempenho de leitura e escrita. O grupo GEB apresentou decréscimo nos testes de atenção com aumento de erros no ditado. Comparando a escolaridade no teste de leitura, o 4º ano diminuiu o tempo de leitura enquanto os sujeitos dos 3º e 5º ano gastaram mais tempo de leitura. **Conclusão:** A interferência auditiva é capaz de influenciar a capacidade de foco de atenção assim como o desempenho de leitura e de escrita em níveis de ruído mais intenso. Não foram observadas influências da escolaridade sobre os efeitos distratores.

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INTRODUCTION

Learning is a broad term that refers to the acquisition of skills and competence on the part of individuals. It ranges from early development of sensory-motor capacities to more complex skills, such as reading and writing[1].

The learning process depends on a convergence of various factors—from exposure to the information to be learned to the biological, social and emotional status of the individual receiving it[2]. Among these factors, cognitive functions such as attention, perception and memory contribute to the learning process. Together, they lead to successful learning, since this depends on the identification and retention of the content to be learned—i.e. identification of the stimulus and subsequent storage in memory[3]. In order for that content to be available when needed, the individual needs to focus attention on the stimulus. Indeed, it is focused attention that allows for content perception and consequent retention. The more aware the individual is, the easier he or she learns. To accomplish this, it is necessary to help students understand the factors that can be extremely important to their learning. This involves selective attention on the desired stimuli and ignoring of possible distracters that may shift attentional focus[4,5].

Therefore, the more neutral the environment is, the better the learning performance[6]. However, although the learning process should be preeminent, the school context is a place full of distractions and competing stimuli[7]. In many cases, this can add to other factors, such as anxiety, disaffection and reduced motivation. In addition to providing more stimuli, the constant presence of external factors may compromise students' attention. This kind of noise should thus be carefully considered and, to the degree possible, controlled[8]. Several studies show that young children are constantly exposed to high levels of noise, including at their learning places. This noise may lead to stress, attentional difficulties, neuropsychomotor development delay, aggressive behavior and poorer learning performance[9-11].

The acquisition domain for the learning process of writing-spelling is extremely complex and involves a wide range of skills of different natures (visual, auditory, motor, knowledge of rules, experience)[12,13]. The importance of verifying the influence of distracters such as noise on students' attention has been acknowledged, as it may lead to learning losses in the realm of reading and writing. Furthermore, recognizing the effects of this potential factor on the learning process is of the essence. It is thus incumbent on school professionals to remain alert to such interferences and take measures to reduce them.

The objective of this study was to verify the effect of noise on children's attentive ability in reading and writing tasks. We also considered how educational levels influenced attentional performance during reading and writing tasks. Additionally, we investigated the relationship between attention and the reading and writing process itself.

METHODS

Students from the third to fifth grades of elementary education from public schools in the city of Porto Alegre, Brazil, were included in the study. The participants' age ranged from 8 to 12 years old and all students were tested for reading and writing skills. Their school records were examined with a view to screen out participants with neurological impairment and auditory and/or visual disabilities. Illiterate students were also excluded from the study. Data collection took place during the school year. All of the participants' legal guardians signed an informed consent form on behalf of the participants. The study was approved by the Research Ethics Committee of the university under registration number 1794/12.

The students were randomly allocated to three groups and submitted to different levels of noise produced by a stereo sound equipment (Mini-System Best Sound - Mondial®) while performing a set of tasks. The three groups were the Control Group (CG), which was not exposed to noise; Experimental Group A (GEA), exposed to 20dB of noise (children's loud conversation); and Experimental Group B (GEB), exposed to interference noise produced at a level of 40dB. The CG performed the task while exposed only to the natural school noise where it was tested. A Victor 824 sound level meter was used to measure the levels of noise.

With a confidence level of 95% and an estimated maximum error of 5%, the sample size was estimated to a total of 162 children. The assessment instruments used were: subtest for Writing under Dictation of the International Dyslexia Test[14], Sustained Attention Test[15] and Isolated Word Reading Test[16-18].

In order to evaluate the quality of students' writing, they were asked to write words dictated by a speech therapist researcher. This consisted of 30 regular and irregular words and 10 pseudowords. The total number of mistakes in each category of words was counted. The isolated words reading task was applied to assess reading time[16-18]. This consisted of 60 stimuli, with 20 in each category (regular, irregular and pseudowords). The students' readings during the task were recorded with a Sony ICD P0630F® voice recorder. This allowed counting of the total time in seconds the students took to complete the reading task for each word category: regular, irregular and pseudo. The Sustained Attention Test[15] was subsequently administered to evaluate attentional focus in a specific time frame. The test has 441 symbols distributed into 21 lines with 21 symbols in each. There are seven target symbols to be identified and marked with a pencil. Allotted execution time was five minutes. Performance on the sustained attention test was correlated to the tests of reading and writing regular, irregular and pseudowords. Additionally, the effect of the noisy environment during the tests was factored in. All students were individually accessed.

The data was statistically analyzed using the Kruskal-Wallis test and the Spearman Rank Correlation test with a significance level of 5%. The SPSS version 20.0 was used.

RESULTS

In the sample of 162 subjects, 51 were in the third grade (31%), 63 were in the fourth grade (39%) and 48 were in the fifth grade (30%). Thirty children were 8 years old (19%), 54 were 9 years old (33%), 46 were 10 years old (28%), 23 were 11 years old (14%) and 9 were 12 years old (6%).

The medians were compared to verify the influence of schooling on performance in the third, fourth and fifth grades (Table 1). Variables on the reading test showed improved reading speed as a result of increasing grade level in all categories. Likewise, the writing test evidenced better performance in all categories of words from dictation, based on grade level. The only exception

Table 1. Comparison of medians per school grade

	Grade 3	Grade 4	Grade 5	P Value
	Median [25%;75%]	Median [25%;75%]	Median [25%;75%]	
TR	38.0 [24.0;56.0]	23.0 [20.0;36.0]	20.5 [16.0;20.5]	<0.001*
TI	53.0 [35.0; 75.0]	34.0 [25.0;47.0]	25.5[22.0;35.75]	<0.001*
TP	61.0 [44.0;81.0]	46.0 [37.0;56.0]	40.0 [34.0;50.0]	<0.001*
TT	149.0 [106.0;206.0]	107.0 [83.0;142.0]	85.5 [71.0;110.50]	<0.001*
ER	4.0 [2.0;9.0]	3.0 [2.0;7.0]	3.0 [1.0;6.0]	0.063
EI	13.0 [9.0;19.0]	9.0 [7.0;13.0]	6.5 [4.0;9.75]	<0.001*
EP	7 [3.0;13.0]	7.0 [4.0;13.0]	7.0 [4.0;13.0]	0.953
ET	24.0 [16.0;37.0]	20.0 [15.0;34.0]	17.5 [11.0;26.0]	0.027*
EAC	52.0 [43.0;63.0]	61.0 [50.0;71.0]	67.5 [60.3;78.0]	<0.001*

*p≤.05
Caption: TR = Reading time for regular words; TI = Reading time for irregular words; TP = Reading time for pseudowords; TT = Total reading time; ER = Errors in regular words; EI = Errors in irregular words; EP = Errors in pseudowords; ET = Total errors; EAC = Correct answers in the attention test

Table 2. Correlation between attention and control of reading and writing skills

Variables	Correlation coefficient	P Value
EAC x TR	-0.287	<0.001*
EAC x TI	-0.327	<0.001*
EAC x TP	-0.319	<0.001*
EAC x TT	-0.329	<0.001*
EAC x ER	-0.217	0.005*
EAC x EI	-0.283	<0.001*
EAC x EP	-0.038	0.634
EAC x ET	-0.199	0.011*

*p≤.05
Caption: TR = Reading time for regular words; TI = Reading time for irregular words; TP = Reading time for pseudowords; TT = Total reading time; ER = Errors in regular words; EI = Errors in irregular words; EP = Errors in pseudowords; ET = Total errors; EAC = Correct answers in the attention test

was the category of pseudowords—these presented the same degree of errors across all educational levels. With regard to attention, the fifth grade performed better compared to the third and fourth grades.

Spearman's test was used to correlate attention to reading and writing, using the medians of all 162 individuals (Table 2). The results showed a negative correlation between the total score on the attention test and the total reading time for each category of words, as well as between the total score on the attention test and the total number of spelling errors in the writing task for each word category.

The medians of the Control Group (CG), the Experimental Group A (GEA) and the Experimental Group B (GEB) of each school grade were compared to analyze the effects of a new stimulus in the environment during the attentional test execution, as well as reading and writing, (Table 3). The reading test

Table 3. Comparison of the medians of the groups per grade

VARIABLE		TR	TI	TP	TT	ER	EI	EP	ET	EAC
3º Grade Median [25%;75%]	GC	39.0 [26.5;66.5]	52.0 [34.5;89.00]	63.0 [42.5;88.5]	149.0 [104.0;237.5]	4.0 [3.0;5.0]	13.0 [7.5;19.0]	4 [2.0;10.0]	19.0 [12.5;33.5]	53.0 [44.5;62.5]
	GEA	42.0 [25.5;57.5]	63.0 [40.5;74.50]	65.0 [53.0;82.5]	170.0 [127.5;206.5]	2.0 [1.0;9.5]	13.0 [8.5;23.0]	6.0 [3.0;12.5]	23.0 [11.0;43.0]	53.0 [46.5;68.0]
	GEB	33.0 [22.5;56.0]	43.0 [33.5;71.50]	54.0 [41.5;80.5]	134.0 [98.5;199.0]	7.0 [3.5;11.0]	14.0 [10.0;19.0]	12.0 [6.5; 16.5]	33.0 [22.5;43.0]	46.0 [39.5;60.0]
P Value		0.678	0.627	0.504	0.627	0.069	0.817	0.018	0.129	0.227
4º Grade Median [25%;75%]	GC	29.0 [21.0;40.5]	42.0 [27.5;57.50]	53.0 [45.0;62.0]	125.0 [87.5;167;5]	3.0 [2.0;5.0]	10.0 [7.5;15.0]	5.0 [2.5;8.0]	19.0[13.5;24.5]	63.0 [47.5;77.0]
	GEA	22.0 [18.0;31.0]	30.0 [24.5;46.50]	46.0 [37.5;56.0]	100.0 [81.5;139.0]	2.0 [0.5;4.0]	9.0 [7.0;11.5]	5.0 [4.0;9.0]	16.0 [11.5;20.5]	59.0 [52.0;75.5]
	GEB	22.0 [19.5;30.0]	28.0 [23.5;40.00]	40.0 [34.5;52.0]	91.0 [79.0;119.0]	7.0 [3.5;9.5]	11.0 [7.5;13.5]	17.0 [8.0;19.0]	34.0 [23.0;41.5]	61.0 [49.5;65.5]
P Value		0.376	0.138	0.05	0.092	0.001	0.497	0	0.003	0.567
5º Grade Median [25%;75%]	GC	19.5 [17.00;33.75]	23.5 [19.75;37.75]	39.5 [34.0;54.25]	82.5 [72.0;123.5]	1.0 [0.0;3.0]	6.0 [3.25;8.75]	4.5 [2.25;6.5]	11.0 [8.25;18.75]	71.0 [63.0;86.0]
	GEA	21.0 [16.00;28.00]	27.5 [21.25;35.75]	38.5 [35.0;60.25]	86.0 [71.0;120.75]	2.0 [1.0;3.0]	6.0 [4.25;7.75]	8.0 [4.25;9.75]	15.0 [11.25;19.5]	74.0 [62.25;80.25]
	GEB	21.0 [15.75;25.75]	25.5 [23.00;33.00]	41.5 [32.5;49.75]	90.5 [69.25;103.25]	6.5 [4.0;8.0]	8.0 [5.5;12.0]	14.5 [12.25;24.75]	30.5 [24.0;41.25]	63.5 [53.75;70.75]
P Value		0.909	0.998	0.971	0.932	0.001	0.207	0	0	0.077

Caption: TR = Reading time for regular words; TI = Reading time for irregular words; TP = Reading time for pseudowords; TT = Total reading time; ER = Errors in regular words; EI = Errors in irregular words; EP = Errors in pseudowords; ET = Total errors; EAC = Correct answers in the attention test. GC = Control Group; GEA = Experimental Group A; GEB = Experimental Group B

showed that the third and fourth grades presented little statistical difference from the fifth grade. While for the fifth grade reading time increased progressively with exposure to noise, in the other two grades, the time generally decreased. An increase in spelling mistakes, particularly in the writing of pseudowords, was also observed. The attention test presented a smaller number of correct responses as a result of the intensity of noise.

DISCUSSION

Language has a fundamental role in the educational process. A primary goal of school is to teach and lead students to master reading and written and spoken language. It is by means of these vehicles that students can acquire knowledge and express it[19]. The reading and writing models, as derived in cognitive neuropsychology, have been used to understand the processes of word reading and writing in children. The dual-route model of reading and writing postulates that the child can use at least two reading processes: a) the phonological process, which involves graphophonemic (reading) or phonographemic (writing) conversion; and b) the lexical process, which uses the representation of known vocabulary, stored in the lexicon, to recognize words (reading) and reproduce them (writing). With continuous progressive learning, students reach a higher level: word recognition and reading occur with greater frequency. Here the availability, by direct lexical access and semantic stores, of certain graphic properties of the word, both adequately stored and correctly spelled, is important. As to writing, the same memory bank is accessed for retrieval of the correct production[20].

This study found that children in the fifth grade performed the reading task for all word categories faster than those in the third and fourth grades. This data is consistent with the literature, which shows that education and normal development allow students to learn and stabilize spelling relationships. This provides for faster content recovery and automatic and appropriate word retrieval, which reduces the frequency of use of the phonological route for reading[20].

As with reading, learning to write is an evolutionary process that takes place in progressive mode. Nobody learns to write immediately; errors are part of the learning process and are only gradually overcome, as children understand in more depth the characteristics of the orthographic system they are using. This means that some aspects of greater complexity will be resolved later while other, more simple aspects will be understood at advanced stages of development of the writing learning process[21]. This justifies the discrepancy between errors found in the category of regular words and irregular words. However, in regular words, one can check the direct correspondence between phonemes and graphemes, facilitating its production, since each sound finds representation in a letter. This is the initial principle of writing and explains the lower number of errors and the linearity of their occurrence over the school years in this category[22]. On the other hand, with irregular words, knowledge influences the learner's spelling and the acquisition of grammatical rules. The letter a student chooses to use depends on his or her familiarity with the word and cannot be deduced by any recognizable aspect[23]. In this way, it explains both the highest number of errors in this category and its decline over the school years. It also suggests that the student's experience with this type of word improves writing performance.

Performance in the category of pseudowords showed a greater number of errors than in the regular words, and fewer in relation to irregular words. Moreover, there was no interference of school grade in students' performance in this category. This may suggest that the same principle was used for the grapheme-phoneme correspondence as verified in regular words, which already exceeds the period of acquisition as students become literate[24]. Also, the slightly higher number of mistakes in this category might be due to their unfamiliarity with these nonexistent words. Thus, they could not be written with the proper support of the mental lexicon store[25].

It is usually argued that the time of schooling may influence reading and writing performance. This may happen not just because of knowledge acquisition from schooling, but also by the experience gained and a natural developmental maturation. Attention is one of the main cognitive processes that significantly grow with maturity. It is well established that age progression improves the capacity of processing information and reduces difficulties in focusing and maintaining attention[26]. Corroborating the literature, this study showed that performances in the sustained attention task improved with progression of the grades.

It is common sense that, to learn successfully, the student must be aware of the content-teaching underway. The more active the neural network is, the higher the potential for synaptic activity and, consequently, learning. In other words, attentive children learn better[13].

The present study showed a significant negative correlation between attention and reading and writing—i.e. the higher the attention test score, the shorter the reading time and the lower the number of orthography mistakes.

In the same way, with higher attention scores, there were fewer spelling mistakes in writing. Therefore, learning reading and writing presupposes intrinsic mechanisms. These involve both the ability to select a specific area of the visual field and to process relevant information and filter out irrelevant information and distracters. This mechanism acts as a filter that accentuates the information of the target or suppresses information of object distracters, or both[5,27].

Research on difficulties in learning of reading and writing and the development of these skills indicates that this process is subject to the interdependence of various factors: biological, cognitive and socio-developmental[2]. Thus, it is necessary to use pedagogical techniques, and conditions that may boost the development of this process should also exist. The proper development of auditory abilities and the presence of favorable acoustic conditions seem to be fundamental to this process within the school environment. In terms of environmental conditions, such noise levels directly affect classroom communication. In consequence, the ability to understand will be affected, hindering the students' learning progress[28]. Noise can interfere with attentional focus, acting as a distractor from the learning priority[29].

The present study observed that the students could cope well with levels of 20dB of noise, as seen in their performance

on the sustained attention task. However, an increase to 40dB above the level of environmental noise (which is considerable) caused a worsening of performance in all grades. This suggests that today's students are accustomed to noise in the school environment. However, when noise is more intense, it causes more difficulty in focusing and maintaining attention. This interference can result in other unwelcome behaviors, such as students' talking in class, which can also produce decrements in learning[7].

Additionally, there is competition between the teacher's speech and other noises and school performance may be impaired in some activities, since the student does not necessarily receive the message issued by the teacher clearly. Although students report that they listen to the teacher, even from the back of the classroom, difficulties in speech intelligibility are not clearly perceived and can lead to mistakes, particularly in dictation situations[29].

The results corroborate other data that shows that writing of words greatly depends on the correct understanding of what was said. As in the observed performance of the students in the attention task, higher levels of noise (40dB) leads to higher levels of writing errors in all of the categories. However, it contrasts with the distribution of errors in the pseudowords category, compared to performance across the groups. This may reinforce the widespread observation that children perform "auditory closure" more productively as they acquire wording experience. The term refers to the completion of hearing what is not heard[30]. In this way, words are filled in, even if they have not been understood in detail, in order to express a recognizable term. Although this process, performed in an automatic way, can lead to word errors, it becomes unfeasible in pseudowords, as auditory closure always results in a recognized word. This explains the difficulty encountered by students in relation to the spelling of these words under the influence of noise[23].

With respect to the results obtained on the reading task, it was observed that more experience with this process results in higher reading speed, possibly due to the use of a lexical route for task performance on the part of the student. According to the literature, it can be assumed that the interference of noise distractors reduces this performance, particularly among students less experienced in the pseudowords category. However, results obtained in the reading test in the fourth graders did not meet these assumptions. A shorter time to accomplishment of the pseudoword tasks by students of the fourth grade as the intensity of the noise distractor increased can be explained by greater focus of attention by the student before a condition adverse to its performance.

CONCLUSION

This study shows that the level of schooling was influential over attentional performance and reading and writing skills. No influence of the educational level on the effects of the distracter noise was found: the higher the noise intensity, the greater its interference on the tests, regardless of the students' grade. However, attentional focus could be compensated by maturity, as the results of the Sustained Attention Test show. The students' cognitive efforts to sustain attention during exposure to noise must be understood as a distraction to be overcome. Therefore, the study shows the importance of a more suitable environment for teaching, acquisition and development of reading and writing. There is a clear need for cooperation among school professionals for analysis and reduction of the negative impact of noise.

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Author contributions

RAF participated in the idealization of the study, data collection, analysis and interpretation, and article writing; DCGMV participated in the idealization of the study, interpretation, and article writing; AAO participated in the condition of guiding, idealization of the study, interpretation and article writing.