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Original Article
Artigo Original

Efficacy of auditory training using the *Programa de Escuta no Ruído* (PER) software in students with auditory processing disorders and poor school performance

Eficácia do treinamento auditivo utilizando o software Programa de Escuta no Ruído (PER) em escolares com transtorno do processamento auditivo e baixo desempenho escolar

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Keywords

Software
Auditory Perceptual Disorders
Hearing
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ABSTRACT

Purpose: Investigate the efficacy of auditory training in students with auditory processing disorders and poor school performance using the software *Programa de Escuta no Ruído* (PER), which addresses auditory processing skills, specifically listening in noise. **Methods:** Eighteen children aged 8-10 years, of both genders, participated in this study. All individuals participated in the following stages: pre-intervention assessment, intervention (consisting of placebo training, re-evaluation of auditory processing, and auditory training), and post-intervention assessment, so that the same individual is self-control. **Results:** No statistically significant difference was observed between the pre-intervention assessment and the post-training auditory processing re-evaluation of the placebo, but statistically significant difference was found between the pre- and post-auditory training conditions. **Conclusion:** The present study achieved its general objective. The PER software proved to be effective for the auditory training of students with auditory processing disorders and poor school performance.

Descritores

Software
Transtornos da Percepção Auditiva
Audição
Aprendizagem
Estimulação Acústica

RESUMO

Objetivo: investigar a eficácia do treinamento auditivo nessa população, utilizando o software Programa de Escuta no Ruído (PER), que aborda, entre as habilidades de processamento auditivo, a escuta no ruído. **Método:** participaram deste estudo 18 crianças com idades entre 8 e 10 anos, de ambos os gêneros. Todos os sujeitos participaram das seguintes etapas: avaliação pré-intervenção, intervenção constituída por treino placebo, reavaliação do processamento auditivo e treino auditivo e reavaliação pós-intervenção, de forma que o sujeito seja controle dele mesmo. **Resultados:** não houve diferença estatisticamente significante entre a avaliação pré-intervenção e a reavaliação do processamento auditivo pós-treino placebo, mas houve diferença estatisticamente significante entre as condições pré e pós-treinamento auditivo. **Conclusão:** o presente estudo alcançou seu objetivo geral. O software PER se mostrou eficaz para o treinamento auditivo em escolares com transtorno do processamento auditivo e baixo desempenho escolar.

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INTRODUCTION

Poor school performance is characterized as a performance below the expected level for age in school grades or tasks, that is, it is the difference between academic aptitude and achievement[1,2], and it may result in emotional disturbances and family concerns[3,4].

Studies have demonstrated that, besides pedagogical techniques, acoustic factors such as background noise, reverberation time, and signal-to-noise ratio may also interfere with learning, which can negatively influence classroom communication[5,6]. In addition to acoustic factors, another important aspect for effective classroom communication is auditory processing, because the normal development of oral and written language depends, in large part, on the adequate processing of auditory information[7,8].

When an auditory processing disorder (APD) is diagnosed, intervention through programs based on auditory training and acoustic signal improvement is necessary in order to promote plasticity and cortical reorganization[9,10].

Auditory training can be conducted in an acoustic booth and/or with the use of software. It is believed that the use of software provides a differentiated and individualized therapeutic approach, in addition to being more stimulating and promoting contact with a therapeutic instrument that enables multiple strategies to potentiate global and auditory development[11,12].

There are several commercially available auditory training programs, and they are widely used by children with learning disabilities[13-15]. Despite the list of software available, there are a limited number of scientific studies that present the benefits of auditory training in individuals with APD and/or poor school performance, especially addressing listening in noise training.

From this finding, a previous study by Calarga[16] translated and adapted to Brazilian Portuguese the Canadian software *Logiciel d'Écoute dans le Bruit* (LEB), designed and developed in laboratory by Professor Benoît Jutras from the University of Montreal, Canada, based on the auditory training programs suggested by Erber[17] and Bergeron and Henry[18], and named it *Programa de Escuta no Ruído* (PER).

This auditory training software aims to improve speech comprehension in noisy environments using games with verbal stimuli presented simultaneously to background noise that changes intensity according to the child's performance in each activity.

The background noise used in this software is that of a cafeteria where a group of people are laughing and talking. Activities were based on the auditory behaviors of detection, identification, and comprehension, whereas linguistic stimuli were phonemes, suprasegmental aspects, words, minimum pairs, maximum pairs, phrases, and texts.

The degree of demand for cognitive, linguistic and auditory skills gradually increases with each activity, and may vary according to the proposed task.

Calarga[16], after translating and adapting the PER software, verified its efficacy in 22 Brazilian schoolchildren, aged 9-10 years, through their performance in auditory, cognitive and linguistic tests. The results showed the proven efficacy of the software to stimulate the skills of auditory closure, auditory comprehension, sustained auditory attention, phonological awareness, and pseudoword reading.

However, the previous study did not verify the efficacy of the PER software in schoolchildren with poor school performance and APDs, thus it is necessary to develop research to investigate its efficacy in the auditory training of schoolchildren with APDs and poor school performance or learning difficulties.

Therefore, the objective of this study was to investigate the efficacy of auditory training using the PER software in students with APDs and poor school performance.

METHODS

This study was approved by the Research Ethics Committee of the aforementioned Institution under protocol no. 111/16.

Study participants were 18 children, of both genders, aged 8-10 years (13 boys and 5 girls) selected according to the following inclusion criteria: absence of current complaints about auditory system disorders; basic audiological evaluation (pure-tone audiometry, logoaudiometry, and immittance testing) within normality (ANSI – 69 standard); absence of motor impairments, cognitive and speech motor development impairments, neurological damage, restricted social interaction, and significant emotional disturbances; auditory processing disorder (APD); poor school performance due to learning difficulties.

The study sample was formed by convenience: all participants were assisted at the Laboratory of Speech-Language Pathology Research in Neuroaudiology and/or belong to the researchers' social relations or were referred by other speech-language therapists.

Parents and/or legal guardians of the children read and signed an Informed Consent Form authorizing their participation prior to study commencement. The children were oriented about the procedures and importance of participating in the research and, after agreeing with them, signed an Assent Form.

All individuals participated in the following stages: pre-intervention assessment, intervention (consisting of placebo training, re-evaluation of auditory processing, and auditory training), and post-intervention assessment. Thus, each individual was self-control, that is, after the placebo training the individual was re-evaluated and referred to auditory training.

The pre-intervention assessment consisted of basic audiological evaluation (meatoscopy, acoustic immittance, and pure-tone and vocal audiometry), auditory processing assessment (Speech-in-noise test - SIN, Pediatric Speech Intelligibility Test - PSI, Staggered Spondaic Word Test - SSW, Frequency Pattern Test - FP), and School Achievement Test (SAT), which evaluates comprehensively the fundamental skills for school performance in the areas of reading, writing, and arithmetic. After that, placebo training composed of 12 sessions, one per week, was performed at the patients' homes. Two activities were proposed for the placebo training sessions: activity 1 (comprising four tasks involving visual processing skills such as perception and discrimination of shapes and sizes, visual closure, figure-ground, and visual memory) should be performed for four weeks (one task per week) and activity 2 (DVD containing eight children's videos) should be conducted for eight weeks (one video per week). Participants were re-evaluated at the end of the 12 sessions.

After conducting the placebo training, only the behavioral re-evaluation of auditory processing was performed in order to verify whether there was improvement in the auditory skills previously assessed. Participants were then submitted to an auditory training program using the PER software, which is composed of 13 themes (sports, insects, cooking, mammals, birds, professions, music, human body, transportation, energy, vegetables, outer space, and countries) containing 19 activities each. These activities are described ahead:

- Activities 1 to 4: auditory discrimination of single words;
- Activities 5 to 7: identification of words in a phrase;
- Activities 8 and 9: identification of single words;
- Activities 10 to 13: identification of phrases;
- Activities 14 to 19: comprehension of short, complex or long texts.

The auditory training was performed individually and comprised 12 weekly sessions of 50 min. It was conducted as follows: first, the child chose a theme of their preference from the 13 themes available and clicked on its icon; next, a playful animation related to the theme was presented; finally, the child was directed to an activity. To advance to the next activity, the child had to achieve ≥70% of correct responses in the proposed tasks. Each time the child finished one theme and started another, the signal-to-noise (S/N) ratio was changed, that is, it was neutral in the first theme (S/N=0), if the child achieved 70% of correct responses in the next theme, the S/N ratio was reduced by 2 dB, successively until stabilization at 10 dBNA.

If the child achieved 30-70% of correct responses in the task, they would redo it with the same S/N ratio, but if the child achieved <30% of correct responses, they would have to redo the task with an S/N ratio 2 dB above the previous value. If the child still did not achieve 70% of correct responses, the activity was presented with the same S/N ratio and the correct responses were pointed on the screen. In this way, the game was always challenging and the child could see their mistakes and have instant feedback.

At the end of the auditory training, all the children were re-evaluated following the same battery of tests used in the pre-intervention assessment. The PER software will soon be available for commercial use.

RESULTS

Multivariate analysis of variance with repetitive measures (MANOVA - repeated measures) was applied to compare the means between the individuals in the three periods studied. In MANOVA, the *p*-value and the *F* ratio (which is used to test the overall difference between groups) were analyzed by means of the Wilks' lambda (λ) test. A significance level of 5% (p=0.05) was adopted for all statistical analyses.

Values considered statistically significant were marked with an asterisk (*) when $p \leq 0.05$, with two asterisks (**) when $p \leq 0.01$, and with three asterisks (***) when $p \leq 0.001$. An octothorpe (#) was used to show trends for significance. In addition to the level of significance, values of the degrees of freedom (*gl*) and of the *F* ratio, which is used to test the overall difference between groups of means in experiments, were informed.

Table 1 shows the study sample distribution according to gender and age. Table 2 presents the mean and standard deviation values of the percentage of correct responses obtained during the placebo training in the pre-intervention auditory processing behavioral assessment of auditory processing and in the post-training auditory processing behavioral re-evaluation of the placebo.

MANOVA - repeated measures showed no multivariate difference between the two assessments of behavioral tests [$F(7.11)=1.732$; $p=0.2$; Wilks' $\lambda=0.476$].

Table 3 shows the mean and standard deviation values of the percentage of correct responses obtained in the post-training

Table 1. Sample distribution according to gender and age

Gender	n	Mean	Age Minimum	Maximum
Male	13	9 y 7 m	8 y 1 m	10 y 11 m
Female	5	9 y 0 m	8 y 0 m	10 y 2 m

Caption: n: number of individuals; y: years; m: months

Table 2. Mean and standard deviation values of the percentage of correct responses in the behavioral evaluation obtained during the placebo training

		Placebo (n=18)			
		Assessment 1		Assessment 2	
		Mean	SD	Mean	SD
PSI	RE	63.33	18.47	64.44	18.22
	LE	60.56	21.27	64.44	22.02
SIN	RE	78.80	8.11	79.00	6.80
	LE	76.80	12.91	78.80	11.14
FP		72.39	19.42	78.05	13.88
SSW	RE	59.31	16.97	62.08	18.52
	LE	56.11	20.22	59.31	18.47

Statistical significance level (p=0.2)

Caption: n: number of individuals; PSI: Pediatric Speech Intelligibility Test; SIN: Speech-in-noise Test; FP: Frequency Pattern Test; SSW: Staggered Spondaic Word Test; RE: Right ear; LE: Left ear; SD: Standard deviation; Assessment 1: pre-intervention auditory processing behavioral assessment; Assessment 2: post-training auditory processing re-evaluation of the placebo

Table 3. Mean and standard deviation values of the percentage of correct responses in the behavioral evaluation obtained in assessments 2 (pre-auditory training) and 3 (post-auditory training)

		Auditory Training - AT (n=18)				Significance level (*p*)
		Assessment 2 (pre-AT)		Assessment 3 (post-AT)		
		Mean	SD	Mean	SD	
PSI	RE	64.44	18.22	73.89	15.39	*p*=0.002
	LE	64.44	22.02	77.78	18.01	*p*=0.001
SIN	RE	79.00	6.80	83.78	6.05	*p*<0.001
	LE	78.80	11.14	84.00	7.88	*p*=0.002
FP		78.05	13.88	84.44	15.14	*p*<0.001
SSW	RE	62.08	18.52	68.19	18.27	*p*<0.001
	LE	59.31	18.47	70.28	17.42	*p*<0.001

Caption: n: number of individuals; PSI: Pediatric Speech Intelligibility Test; SIN: Speech-in-noise Test; FP: Frequency Pattern Test; SSW: Staggered Spondaic Word Test; RE: Right ear; LE: Left ear; SD: Standard deviation; Assessment 2: post-training auditory processing re-evaluation of the placebo; Assessment 3: post-intervention auditory processing behavioral re-evaluation

Table 4. Mean and standard deviation values of the percentage of correct responses in the School Achievement Test (SAT) at the pre- and post-auditory training assessments

	Auditory Training (n=18)				Significance level (*p*)
	Pre-AT Assessment		Post-AT Assessment		
	Mean	SD	Mean	SD	
Reading	46.44	19.88	48.00	19.71	*p*=0.02
Writing	17.17	9.88	18.06	9.92	*p*=0.05
Arithmetic	13.00	5.88	13.94	5.73	*p*=0.02

Caption: SD: standard deviation; AT: auditory training; n: number of individuals

auditory processing behavioral re-evaluation of the placebo and in the post-auditory training auditory processing behavioral re-evaluation.

MANOVA - repeated measures showed multivariate difference between the pre- and post-auditory training conditions regarding behavioral evaluation of auditory processing [$F(7.11)=15.03$; $p<0.001$***; $\eta^2_{partial}=0.905$; Wilks' $\lambda=0.095$].

Table 4 presents the mean and standard deviation values of the percentage of correct responses obtained in the School Achievement Test (SAT) pre- and post-auditory training.

MANOVA - repeated measures revealed a marginal multivariate difference between pre- and post-auditory training conditions for the assessment of the SAT [$F(3.15)=2.96$; $p=0.066^{\#}$; $\eta^2_{partial}=0.372$, Wilks' $\lambda=0.628$].

DISCUSSION

The 8-to-10-year-old age group was chosen because at this age children have already reached auditory neural maturation, which enables assessment of the auditory processing without impediment[8], as well as because children in this age group are in Elementary School grades that allow evaluation by the School Achievement Test (SAT).

With respect to the gender factor, a larger number of male individuals were observed in this study (Table 1). Predominance of the male gender may be associated with the fact that boys are at greater risk of language impairments and auditory processing disorders (APD) than girls[19,20].

In the overall comparative analysis, no statistically significant difference was found between of the pre-intervention behavioral assessment of auditory processing (Assessment 1) and the post-training auditory processing behavioral re-evaluation of the placebo (Assessment 2). In other words, the mean results of Assessments 1 and 2 (Table 2) suggest that no real efficacy of the placebo training was observed in Assessment 2.

These results are in agreement with those of several other studies in which statistically significant differences were observed in the post-auditory training assessments[21,22].

A survey conducted by Anderson et al.[21] verified efficacy of auditory training for speech-in-noise processing using a placebo training method similar to that of the present study. Anderson et al.[21] used educational videos and multiple-choice questions about content, a methodology similar to the placebo training conducted in this study, which also used educational videos and directed questions about each theme. In both studies, no statistically significant changes were observed regarding the placebo training groups.

Morais[22] also used a placebo training method similar to that of this study. Individuals in the aforementioned study were divided into two groups: eight of them were referred to the placebo group and underwent placebo training, whereas the other eight were referred to the non-intervention group and did not undergo training. For the placebo training, a DVD containing eight videos or an e-mail message with Web-available links to eight documentaries on a variety of themes was delivered. After that, the individuals answered questions about each video just as in the present study. Twelve weeks later, individuals from both groups were re-evaluated and referred to auditory training. The results of both studies showed no statistically significant differences in the auditory processing behavioral assessment in the pre-intervention auditory re-evaluation, and occurrence of placebo and test-retest effects were discarded.

Performance of the individuals in the pre- and post-auditory training assessments for the behaviorally assessed skills showed that the auditory training proposed in this study was effective (Table 3), that is, training using the PER software was able to stimulate auditory processing skills. These data corroborate the findings of other studies that reported improvement of hearing abilities in children after auditory training using software[23,24].

The study by Hayes et al.[23] investigated plasticity of the central auditory pathway in children with learning disabilities using the Earobics Step I and Step II software for auditory training. Findings from these authors differed from those of this study with respect to the target audience and the software applied considering that in the present study the target audience are children with poor school performance and the software used is the PER; however, the results are similar, as both studies showed statistically significant differences in the of post-intervention auditory processing behavioral assessment.

In the research by Krishnamurti et al.[24], patients with APDs were submitted to eight weeks of auditory training, with 50 min sessions, five times a week, using the Fast ForWord software, which differs from this study, in which children with APD and poor school performance underwent 12 weeks of auditory training, with 50 min sessions, once a week, using the PER software. The results were similar, that is, both studies presented statistically significant differences in the post-intervention auditory processing behavioral assessment.

In the pre-intervention evaluation, the schoolchildren presented poor performance in the three subtests (reading, writing, and arithmetic) of the SAT, which was already expected considering that they presented learning complaints. Nevertheless, the results showed statistically significant improvement after auditory training for the reading and writing variables, suggesting that the PER software was effective to stimulate grapheme-phoneme decoding, because there is influence of training on phonological awareness - a skill associated with good reading and writing performance.

For the initial learning of reading and writing to occur, it is necessary to perceive acoustic information to decode and encode phonemes; therefore, the children in this study who presented poor school performance also presented difficulties in processing the speech stimuli, showing inability in the processing tests involving verbal stimuli, such as the SIN, PSI, and SSW tests, as it can be observed in Table 4.

Thus, children may encounter obstacles in segmenting and manipulating the phonological structure of language and, consequently, they will be subject to difficulties in reading and writing[25,26]. However, after performing the auditory training, they showed improvements in the reading and writing skills, indicating that the PER software assists with this perception of acoustic information, leading to improved decoding and encoding of phonemes.

The arithmetic variable was applied and analyzed because the aim of this study was to verify poor school performance as a whole, and this variable is part of the test applied for that purpose; however, it is believed that its positive post-auditory training result is due not only to improvement in post-training reading and writing skills, but also to progress in the learning of this content in the school environment. As previously mentioned, the PER software assisted with improvement of post-training reading and writing skills, mainly through stimulation of the phonological awareness. Reading is considered the basis for the structuring of writing and arithmetic, and the skills needed for arithmetic acquisition are associated with the ability to comprehend language, reading, and writing[27-29]. Thus, it can be inferred that improvement in the arithmetic variable post-auditory training may be due to development of the reading and writing skills.

As previously mentioned, the school environment is another aspect that may have assisted with improvement of the arithmetic variable post-auditory training. The schoolchildren were submitted to 12 sessions to finalize the auditory training throughout three months. Over these months, there was advance of the knowledge taught in school, which could have interfered positively with the result of the post-auditory training re-evaluation of the SAT arithmetic subtest.

Therefore, it is possible to conclude that the PER software proved to be effective in stimulating the reading, writing and arithmetic skills of schoolchildren with poor school performance and APDs, because it contemplates the auditory and phonological awareness skills, which could be verified by the evolution of the individuals in the post-auditory training phase. Another aspect worth noting is the acceptance of the software by the study sample, considering that the schoolchildren reported that they liked it and were looking forward to each training session, in addition to the acceptance from the part of parents and/or legal guardians who reported having noticed improvements in their children.

CONCLUSION

The present study achieved its general objective. The PER software proved to be effective for the auditory training of schoolchildren with auditory processing disorders (APD) and poor school performance. No evidence of placebo effect was found in students with APDs and poor school performance.

As for the behavioral assessment of auditory processing, comparison between the pre- and post-auditory training conditions showed improved performance of the auditory skills evaluated in the PSI, SIN, FP, and SSW tests. With respect to the SAT, comparison between the pre- and post-assessments showed improved performance of individuals regarding the skills evaluated in the reading, writing and arithmetic subtests.

Therefore, auditory training using the PER software has proved to be effective in improving performance in the auditory skills, as well as in the abilities assessed by the SAT in this study.

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Author contributions

PDB participated in the study design, collection, analysis and interpretation of data, and writing of the manuscript; ES was the study adviser, and participated in the study design, analysis and interpretation of data, and writing of the manuscript.