Original Article

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Effects of computerized auditory training in children with auditory processing disorder and typical and atypical phonological system

Efeitos do treinamento auditivo computadorizado em crianças com distúrbio do processamento auditivo e sistema fonológico típico e atípico

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ABSTRACT

Purpose: To investigate the effects of computerized auditory training (CAT) through performance analysis of behavioral tests and Scale of Auditory Behaviors (SAB), in children with Auditory Processing Disorder (APD) and typical and atypical phonological system. **Methods:** Forteen children with APD, seven children with APD and typical phonological acquisition (G1) and seven with APD and atypical phonological acquisition (G2) participated. It was performed an auditory processing behavioral evaluation with Random Gap Detection Test (RGDT), Pediatric Speech Intelligibility test (PSI), Nonverbal Dichotic Test (NVDT) and SAB. For composition of the groups it was performed a Child Phonological Assessment. The therapeutic intervention was performed using the Escuta Ativa software, with 12 sessions held twice a week. Appropriate statistical tests were used. **Results:** In the performance in behavioral tests of auditory processing (AP), pre-and post-CAT, there was a significant result in RGDT and NVDT, hearing stage directed to the left in both groups and NVDT to the right only in G2. There was a positive correlation between SAB and some listening conditions of the PSI test in both groups, including pre and post-CAT. Moreover, there was a negative correlation between SAB and the RGDT test post-CAT in the group with typical phonological acquisition and APD. SAB proved to be a useful tool to measure the effect of CAT. **Conclusion:** CAT was effective to improve/adapt the gnosis auditory processes in the studied school groups. There was a correlation between behavioral tests and the score in the SAB.

Keywords: Auditory perception; Child; Articulation disorders; Acoustic stimulation; Software

RESUMO

Objetivo: Investigar os efeitos do treinamento auditivo computadorizado (TAC) por meio da análise do desempenho em testes comportamentais e da Escala de Funcionamento Auditivo (SAB), em crianças com distúrbio do processamento auditivo (DPA) e sistema fonológico típico e atípico. **Métodos:** Participaram 14 crianças com DPA, sete crianças com DPA e aquisição fonológica típica (G1) e sete com DPA e aquisição fonológica atípica (G2). Foi realizada a avaliação comportamental do processamento auditivo com o Teste de Detecção de Intervalo Aleatório (RGDT), Teste de Inteligibilidade Pediátrica (PSI), Teste Dicótico Não Verbal (TDNV) e Escala de Funcionamento Auditivo (SAB). Para composição dos grupos realizou-se a Avaliação Fonológica da Criança. A intervenção terapêutica foi realizada por meio do *software* Escuta Ativa, com 12 sessões, duas vezes por semana. Utilizou-se testes estatísticos adequados. **Resultados:** No desempenho nos testes comportamentais do processamento auditivo (PA), pré-TAC e pós-TAC, o resultado foi significativo no RGDT e TDNV, etapa de escuta direcionada à esquerda em ambos os grupos e TDNV à direita apenas no G2. Houve correlação positiva entre SAB e algumas condições de escuta do teste PSI em ambos os grupos, tanto pré-TAC quanto pós-TAC, além de correlação negativa entre a SAB e o teste RGDT pós-TAC, no grupo com aquisição fonológica típica e DPA. A SAB mostrou-se um instrumento útil para mensurar o efeito do TAC. **Conclusão:** O TAC mostrou-se eficaz para melhorar/adequar os processos gnósicos auditivos em escolares dos grupos estudados. Houve correlação entre os testes comportamentais e o escore na SAB.

Descritores: Percepção auditiva; Criança; Transtornos da articulação; Estimulação acústica; Software

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INTRODUCTION

Hearing is the sense that allows the child to have contact with the world of sounds, including the phonemes that compose the speech, which are examples of acoustic stimuli present in his/her life, since very early. Therefore, the hearing is characterized as the main means of access to the development of speech. Thus, it is necessary to understand the role of Auditory Processing (AP) in childhood, because it was defined as a set of processes and mechanisms that occurs within the auditory system, from the detection to the analysis of the acoustic stimulus. The AP involves a number of phenomena, such as location and lateralization of sound; discrimination and auditory pattern recognition; temporal aspects of hearing, including resolution, masking, integration and ordering; hearing performance with competitive acoustic signals and degradation of the acoustic signal[1]. Briefly, the AP can be defined as a set of skills that allows the subject to understand what was heard[2].

In addition the changes in the PA, called Auditory Processing Disorder (APD), children may have difficulty in speech acquisition process[3,4]. In such cases, there may be a Phonological Disorder (PD), which is characterized by omission or substitution of phonemes during speech, beyond 4 years of age[5]. Thus, such children would present the called atypical phonological system[6].

In many cases, children with PD manifest greater difficulties in AP tests involving the ability of selective attention[3,4], the ability of temporal resolution related to the recognition of language phonemes, the decoding and temporal organization[3].

As recommended by the American Speech-Language Hearing Association (ASHA)[1], AP skills are accessed through hearing tests that include analysis of different auditory gnosis processes, with verbal and non-verbal stimuli for verification of different regions of brain answers the sound stimuli. It must be considered the age of the subjects for the choice of tests, as there is influence of maturation in the responses. Besides that, to the selection of tests, it is highlighted the importance of analyzing the presence of comorbidities, peripheral hearing, the level of language development, speech development, motivation and fatigue at the time of assessment[1]. As the ASHA refers both to the audiologist as other professionals, all should help, providing data on speech, language and cognitive function of the subject evaluated, to collaborate with the diagnosis. The results in behavioral tests bring to light shortcomings of AP in functional level[7]. To complete diagnosis of APD, it is considered the presence of change in one or more hearing skills, taking into account that the examination has been performed in an acoustically treated environment, in a motivational way and with appropriate tests[1].

One of the classifications used for APD relates itself to the loss in gnosis processes. They are: encoding - Ability to integrate auditory information with not auditory; Decoding - ability to integrate sound stimuli, adding meaning to them; organization - ability to sort the sounds in time space[8] and non-verbal gnosis - ability to perceive suprasegmental aspects, such as intensity, frequency and duration[9].

In addition, for investigation of suspected APD, the self-assessment protocols and/or questionnaires that allow verifying the auditory behavior in school and social activities are useful. The Scale of Auditory Behaviors (SAB) protocol, created by Schow and Seikel[10], which in Brazil is called Escala de Funcionamento Auditivo[11] is a tool that can be used to access the perception of the subjects regarding their restrictions and behavioral hearing difficulties, in different degrees and in everyday situations.

After the completion of diagnosis, one of the therapeutic indications is the auditory training[12], which can be performed in different ways, according to the needs of each case. One of the latest strategies is the Computerized Auditory Training (CAT), with software use, as it represents an interesting method to be adopted, especially in children therapy[12]. It is a contemporary approach that uses as a reward positive or negative reinforcements during the performance of activities in the game itself, generating motivation and interest. In addition, it allows the subject to have direct access to the therapy device[13]. Among the advantages of using software it is the stimulus control and hierarchy of activities[14] and perhaps its greatest distinction in relation to other therapies is the possibility that different individuals perform the same activity, due to the standardization of training[15]. In addition, the use of information technology is stimulating to the child population and enables improvement of auditory abilities in the presence of APD[13]. Thus, it is a current and innovative approach, however, its effects and effectiveness should be explored and tested for proper use and improves the quality of life of the subjects.

Considering the problems presented, this study aimed to investigate the effects of CAT through the *Escuta Ativa* software in children with APD and typical and atypical phonological system, in behavioral tests and score on the SAB scale. In addition, it was sought to verify whether there is a correlation between the auditory processing tests and the score shown in SAB scale, pre-CAT and post-CAT.

METHODS

This research is a comparative, cross-sectional, longitudinal and experimental study approved by the Ethics Committee of the *Universidade Federal de Santa Maria*, under number 43171715.0.0000.5346. Regarding the ethical issues and respecting the recommendations required for research involving human beings (Resolution No. 466/12), it was delivered to the responsible for the children, to sign, the Term of Free and Enlightened Consent and, to the children, the Term of Child Assent, both presenting the research objectives, as well as its stages of completion.

The eligibility criteria were: agreement on participation in the study after signing the two terms; ages between 7 years

and 8 years and 11 months; auditory thresholds within normal limits; diagnosed APD with the completion of behavioral assessments (alteration in at least one hearing ability and corresponding gnosis process, as recommended by ASHA[1]); being a member of monolingual family, speaker of Brazilian Portuguese; atypical phonological acquisition (in this case, exclusive phonological disorder), or typical. Those who presented phonological system appropriate to the age were considered children with typical phonological acquisition and those who made omissions or substitutions of speech sounds during speech[5] were considered children with atypical phonological acquisition.

The settled exclusion criteria were: evident neurological, emotional and/or cognitive commitment; oral language disorders, such as stuttering, cleft palate, unique phonetic deviation, among others; language disorder associated with phonological disorders; regular use of musical instruments; evident motor or organic changes; having carried out some form of auditory training previously or being in speech stimulation therapy.

To compose the study, children were received forwarded by four public state schools, acquired through disclosure in social networks, originating from research projects and internships of a Speech Therapy graduation course. Although, only were chosen children who were not receiving any kind of therapeutic intervention. The initial total of children was 105. The responsible of 77 were contacted, because the others had the wrong contact number, or were unwilling to participate. Considering this total of 77 children, 25 did not attend the previously scheduled evaluations, even with rescheduling, and eight did not fit in the age group and were referred to other projects. Thus, 44 children attended to auditory evaluation processing, 28 of male gender and 16 of female gender, 18 of which showed APD. However, three did not want to adhere the therapy and one moved out the city during the therapeutic process.

The final composition, considering the eligibility criteria, was 14 children aged between 7 years and 8 years and 11 months, divided into two groups: G1 - seven children diagnosed with APD and typical phonological system and G2 - seven children diagnosed with APD and atypical phonological system. Regarding the gender classification in each group, it was observed that, in G1, 71% (n=5) were male and 29% female (n=2), while in G2, 43% (n=3) were male and 57% (n=4), female. The average age of the groups was 7 years and 9 months in G1 and 8 years and 1 month in G2.

In relation to the hearing assessment procedures, the children underwent visual inspection of the external auditory canal, pure tone audiometry, logoaudiometry and acoustic immittance measures, in order to select those with hearing thresholds within the normality range. The basic audiological tests and AP behavioral tests were conducted in a soundproof booth, with digital two-channel audiometer, Madsen® brand - GN Otometrics, Itera model, type II, with TDH headphones - 39 with calibration, according to standard ISO 11957-1986. For the measure of the acoustic impedance and auditory reflection, it was used probe tone of 226 Hz and immittanciometer AZ26, Interacoustic® brand, with TDH 39P headphones. The children were not subjected to any hearing ability screening test, such as the Dichotic Digits Test (DDT), because one of the objectives of this study was to verify the effects of CAT in different gnosis processes and listening skills of figure-ground for verbal and non-verbal sounds and temporal resolution, therefore, not being necessary to know its performance in DDT.

Later, as data collection procedures three behavioral tests were conducted to assess auditory processing: Random Gap Detection Test (RGDT)[16]; Pediatric Speech Intelligibility test (PSI)[17] and Nonverbal Dichotic Test (NVDT)[18].

The RGDT evaluates the temporal resolution by presenting pure tones, with intervals of 2 to 40 ms in a random way, intensity of 40 dB above the tritone average. It was considered as range detection threshold the one in which the children could see, consistently, the presence of two intervals in the smallest difference presented. However, if children understood the assessment, but did not obtain consistent answers, we chose to do the RGDT in the expanded version, in which the difference in milliseconds between stimuli are greater. For children without changing the time resolution ability, it is expected to have as responses the perception of silence intervals up to 10 ms, those with 8 or more years and 15 ms for those with 7 years. Each child was instructed to indicate with a finger or two, corresponding to hear a tone or two.

The PSI though, consists of ten sentences and their respective representative figures. The children were instructed to hear a story and to point out the image corresponding to the sentence that was presented simultaneously to the story, and the images were previously shown to the children for information. The test was performed with competitive message presentation of ipsilateral mode - MCI (competition in relation zero and -15 dB) and contralateral - MCC (competition in relation zero and - 40 dB).

The last test performed was the NVDT, which has six non-verbal sounds (onomatopoeia), presented in pairs (one tone in each ear simultaneously). So, it was asked the children to tell which sound they heard better in free listening. In the directed hearing assessment, they should just say the sound heard in the requested ear, pointing to the image corresponding to the sound. The equivalent figures were exposed in the soundproof booth and the level of intensity of the presentation of stimuli was 50 dBNS. It is noteworthy that the free listening responses were not considered, because none of the evaluated children presented alteration at this stage.

The SAB scale[11] was used for learning of limitations and difficulties perceived by parents or guardians of the children in everyday activities. This scale consists of 12 items related to behavior and should be answered this way, regarding the frequency of occurrence observed in the subject's daily life: often, very often, sometimes, sporadic or never. Each response

has a score ranging from 1 (frequent) and 5 (never) and, at the end, is held the sum of points, which can vary between 12 and 60. According to the recommendations of the authors of the protocol, the values should be interpreted as follows:

- Approximate values to 46 points indicate auditory behavior appropriate for the age group 8-11 years;
- Values below 35 points indicate the need for routing for evaluation of auditory processing;
- Values lower than 30 points are indicative of auditory processing disorder, showing, thus, need of intervention and long-term accompaniment.

The total age average of sample, without distinction of groups, was 8 years. It was chosen to use the SAB scale as a way of measuring the therapeutic effect, to be used when comparing pre and post-therapeutic intervention. Therefore, the age of the child on the scale application was not considered as strongly, because the focus was to compare the change after CAT.

For composition of groups, before the therapeutic intervention, all children underwent assessment of phonological system, through spontaneous appointment, with the aid of the five thematic figures that make up the Phonological Assessment of Children (AFC)[19]: "vehicles", "room", "kitchen", "toilet" and "zoo". Later, there was a contrastive analysis and the percentage calculation of Revised Correct Consonants (PCC-R)[20], based on the calculation of the Percentage of Correct Consonants (PCC), which does not consider the phonetic distortions as errors. The evaluation was performed by the researcher and an experienced assessor, characterized as analysis with double-blind method, since none of them was aware of the analysis of each other.

The CAT was performed by the software *Escuta Ativa*[21], in 12 sessions distributed in a frequency of twice a week, lasting approximately 30 minutes each. It was used an above-ear phone, Sony brand, MDR-ZX100 model. One activity per session was held, respecting the same order of presentation for all children, as Chart 1.

All activities had four difficulty levels: easy, medium, hard and insane. In the last level, there was presence of competitive noise. There was also a time limit for children to provide the answer to the proposed activity, however, in this study, this time was not considered. Thus, it was used the opportunity of "pause" to allow more thinking time for the children.

To monitor the development originating from the CAT, a reassessment was performed two weeks after completion of therapy, with the same evaluations mentioned above (behavioral assessments) and the SAB Scale protocol[11]. The phonological system was also evaluated, but it was not the focus of this research.

For data analysis, it was used the McNemar exact test for categorical variables and the Wilcoxon test to compare the pre-CAT and post-CAT evaluations. The significance level adopted was 5% ($p<0.05$). As for the analysis of the scores obtained in the SAB scale and performance in behavioral AP ratings, it was used the Spearman correlation test with the following coefficients and correlation values (r): 0 to 0.25: very weak; 0.25 to 0.50: weak; 0.5 to 0.75: moderate; 0.75 to 0.9: strong and 0.9 to 1: very strong.

RESULTS

The descriptive analysis and statistical study, considering the performance on selected behavioral tests (normal or abnormal), in both groups, pre-CAT and post-CAT showed significant results in RGDT test ($p=0.045$ G1 and 0,025 G2) and NVDT hearing stage directed to the left ($p=0.014$ G1 and 0.046 G2) in both groups and to the right only in G2 group ($p=0.046$) (Table 1).

Regarding the SAB Scale, also used to measure the effect of the proposed therapeutic intervention, it was conducted a research of pre-CAT and post-CAT scores, comparing them between groups (Table 2).

The SAB scale proved to be a useful tool to measure the effect of CAT. As for the perception of auditory behavior by the parents, in both groups, pre-CAT and post-CAT, there was a statistically significant relationship ($p<0.05$). The G2 average always presented itself higher than the G1.

As for the performance in SAB scale, behavioral auditory processing tests were analyzed considering all subjects without distinction of groups. It was possible to observe moderate positive correlation only pre-CAT, in PSI MCC tests left ear (zero relation), NVDT hearing stage directed to the right and RGDT (Table 3):

It was also attempted to investigate the correlation between performance on SAB scale and behavioral tests of auditory processing between the groups (Table 4).

Thus, it was observed that the G1 had a strong positive relationship in MCI stage in the right ear (relation -15 dB) post-CAT and moderate MCC step in the left ear (relation -40 dB) and RGDT pre-CAT. It was observed also moderate negative correlation with the post-CAT RGDT. As for the G2, it was obtained strong correlation in the MCC stage in the left ear (zero relation) and moderate in MCC stage in the right ear (zero relation), MCC left ear (relation -40 dB) and MCI right ear (relation -15 dB).

DISCUSSION

It was opted for the choice of behavioral tests RGDT[16], PSI[17] and NVDT[18], because different gnosis processes were evaluated (decoding, encoding and non-verbal gnosis, respectively). Moreover, the choice of these behavioral tests is justified when considering the prior ignorance of the phonological system of the child at the time of evaluation, which could harm the analysis of the examiner and the child's performance. Thus, non-verbal tests were chosen, because they would not suffer interference of a possible speech alteration.

Chart 1. Proposed activities, stimulated auditory skill, involved gnosis process and brief explanation of the tasks

Activity	Hearing ability stimulated	Gnosis process	Operation
Follow the flute	Ordenação temporal (Padrão de duração) Atenção e Memória	Nonverbal gnosia	Long or short duration sounds were presented and the child was asked to reproduce the same sequence heard. Easy and medium levels with presentation of three sounds, difficult with four sounds and insane with five sounds.
Follow the piano	Temporal patterning (frequency standard) Attention and Memory	Nonverbal gnosia	Sounds of different intensities (treble or bass) were presented and the child was asked to reproduce the same sequence heard. Easy and medium levels with presentation of three sounds, difficult with four sounds and insane with five sounds.
How many intervals	Temporal resolution Attention	Decoding	Sounds and intervals were presented and, in this activity, when the child realized the break, He/she should click on a number or, at the end of the sequence, only in the corresponding number to the total of intervals heard.
How many sounds	Temporal ordering Attention	Nonverbal gnosia	Sounds of musical instruments in different sequences Were presented and the child was requested to tell how many times He/she heard the sound.
Which sound was heard	Detection and discrimination Attention	Ordenation	Two verbal sounds and a question regarding what was heard (the words were the same or different) were presented.
Follow the sequency	Association Auditory memory for nonverbal sounds Attention	Organization	Animal sounds were presented. The child should memorize and organize them as the requested order. Easy and medium levels: put in alphabetical order the names of the animals heard, put in reverse alphabetical order the names of the animals heard, say only the third sound heard, etc. For this activity, the children had visual aid of an alphabet track. Difficult and insane levels: a story was heard and, at the end, a question that the child should interpret was presented.
Listening and attention	Recognition Auditory closure Attention	Decoding	Two words were presented aurally and in writing and the child should respond as requested in the statement (do the words rhyme? Do they start with the same sound? Do have the same number of syllables? etc). Difficult and insane levels: the written and heard words were different.
Right on the sight	Binaural separation Attention	Codification	Two words were presented at the same time, one in each ear, and the child was requested to identify the target word and pointed out which side it was presented. The word target could be said before or after the presentation.
Left Right	Binaural integration	Codification	Words were presented, sometimes on one side, sometimes on the other, and the child should identify which were the words and which side each they came from. Easy level: one word on each side, middle level: two, difficult level: three and insane: four.
Binaural	Location Attention Memory	Decoding	Musical instrument sounds were presented, sometimes on one side, sometimes on the other, sometimes from far, sometimes near, and the child should identify the location where each sound came from. Easy and medium levels: the answer could be given as the stimuli were being heard. Medium and insane levels: the answer was given after the presentation of the sequence, requesting memorization.
Catch if you can (bonus track)	Attention	Codification	A fuit trail was presented and the child should click only on the Apple that was moving. Easy and medium levels. Only apples on the trail, changing speed ou changing size. Hard level: other fruit were added and the child shoul search only for the Apple. Insane level: different fruit on the trail and costumers orders were heard; following request in the statement, the child should click on the fruit that was blinking or on the fruit requested aurally.
Follow the rhythm (bonus track)	Attention	Nonverbal gnosia	Different musical rhythms were presented and the child could choose which he/she wanted to play; they should listen to music and click on the colored chips that were falling.

Table 1. Descriptive analysis and statistical study of categorical variables: performance in behavioral tests for normality in the pre and post computerized auditory post-training groups in students with auditory processing disorder and acquisition typical or atypical speech

	G1 (n=7)					G2 (n=7)				
	Pre-CAT		Post-CAT		p-value	Pre-CAT		Post-CAT		p-value
	Normal	Altered	Normal	Altered		Normal	Altered	Normal	Altered	
PSI										
MCC RE (Relation S/N zero)	57.14%	42.86%	100%	0.0%	0.083	85.71%	14.29%	100%	0.0%	0.317
MCC LE (Relation S/N zero)	57.14%	42.86%	100%	0.0%	0.083	71.43%	28.57%	100%	0.0%	0.157
MCC RE (Relation S/N -40)	71.43%	28.57%	100%	0.0%	0.157	71.43%	28.57%	100%	0.0%	0.157
MCC LE (Relation S/N -40)	57.14%	42.86%	100%	0.0%	0.083	100%	0.0%	100%	0.0%	1.000
MCI RE (Relation S/N zero)	57.14%	42.86%	100%	0.0%	0.083	100%	0.0%	100%	0.0%	1.000
MCI LE (Relation S/N zero)	71.43%	28.57%	100%	0.0%	0.157	100%	0.0%	100%	0.0%	1.000
MCI RE (Relation S/N -15)	85.71%	14.29%	100%	0.0%	0.317	100%	0.0%	100%	0.0%	1.000
MCI LE (Relation S/N -15)	71.43%	28.57%	100%	0.0%	0.157	100%	0.0%	100%	0.0%	1.000
NVDT										
DE RE	14.29%	85.71%	42.86%	57.14%	0.157	14.29%	85.71%	71.43%	28.57%	0.046*
DE LE	0.0%	100%	85.71%	14.29%	0.014*	28.57%	71.43%	85.71%	14.29%	0.046*
RGDT	71.43%	28.56%	85.71%	14.29%	0.046*	0.0%	100%	71.43%	28.57%	0.025*

*Significant values (p<0.05) – McNemar's exact test to compare categorical variables intragroup
Subtitle: CAT = computerized auditory training; PSI = Pediatric Speech Intelligibility; S/R = sinal noise; RGDT = Random Gap Detection Test; NVDT = Nonverbal Dichotic Test; MCC = contralateral competitive message; MCI = ipsilateral competitive message; RE = right ear; LE = left ear; DE = directed attention

Table 2. Score obtained in Scale of Auditory Behaviors pre and post-computerized auditory training comparing the groups, according to behavioral changes reported by parents or guardians of children studied

	G1 (n=7)		G2 (n=7)		p-value
	Average	SD	Average	SD	
SAB-Pre CAT	27.29	9.79	39.43	10.11	0.041*
SAB- Post CAT	40.57	6.05	49.00	5.10	0.025*

*Significant values (p<0.05) – Wilcoxon test for related samples
Subtitle: SAB = Scale of Auditory Behaviors; CAT = computerized auditory training; SD = standard deviation

A significant improvement was observed in the auditory abilities of non-verbal sounds recognition in directed listening and figure-ground for such sounds (NVDT test) and temporal resolution (RGDT), after CAT, in both groups (Table 1). These findings agree with a recent study in which the researchers verified significant changes in hearing abilities, particularly in sustained attention, and cognitive, after CAT, with non-verbal auditory stimulation and phonological approach in children with speech alteration[22].

Regarding the improvement in temporal resolution ability, it was verified that the use of other software were also effective to adapt such skill in the presence of APD[13,14]. It is noteworthy that, during the course of RGDT test, the attentional system is also required, because the child must remain alert to identify if one or two sounds were presented, essential ability to regulate and perform the activity quickly[14].

It is noteworthy that, when assessing the temporal resolution test in the pre-CAT moment, three children of G2 and two of G1 failed to perform the normal version and the expanded version of the test, even though they were guaranteed the understanding of the exam. After the CAT, two children of the G2 and one of G1 maintained that difficulty with the achievement of the test, and the G1's child presented the worst performance during the intervention process, fact that may have hindered the consolidation of the child's learning. It is believed that the changed result, showing the inability of the population of

Table 3. Correlation analysis of the Scale of Auditory Behaviors and performance in behavioral assessments, pre- and post computerized auditory training, to the whole sample (n=14)

	Pre-TAC		Post-TAC	
	r (Spearman)	p-value	r (Spearman)	p-value
PSI				
MCC RE (Relation S/N zero)	0.42993	0.1249	0.31064	0.2797
MCC LE (Relation S/N zero)	0.54176*	0.0454	0.02540	0.9313
MCC RE (Relation S/N -40)	0.09630	0.7433	0.40644	0.1493
MCC LE (Relation S/N -40)	0.33909	0.2356	-0.12701	0.6652
MCI RE (Relation S/N -15)	0.03212	0.9132	0.27742	0.3369
MCI LE (Relation S/N -15)	0.25497	0.3790	0.18774	0.5204
NVDT				
DE RE	0.54990*	0.0416	0.09574	0.7448
DE LE	0.44335	0.1123	-0.29669	0.3030
RGDT	0.63333*	0.0671	-0.47826	0.1367

*Significant values (p<0.05) – Spearman's correlation coefficient (r), considering r = 0 to 0.25: very weak; 0.25 to 0.50: weak; 0.5 to 0.75: moderate; 0.75 to 0.9: strong and, 0.9 to 1: very strong

Subtitle: CAT = computerized auditory training; PSI = Pediatric Speech Intelligibility; S/N = sinal noise; RGDT = Random Gap Detection Test; NVDT = Nonverbal Dichotic Test; MCC = contralateral competitive message; MCI = ipsilateral competitive message; RE = right ear; LE = left ear; DE = directed attention

Table 4. Correlation analysis of the Scale of Auditory Behaviors and performance in behavioral tests pre and post computerized auditory training in children with auditory processing disorder and typical or atypical speech acquisition

	G1 (n=7)				G2 (n=7)			
	Pre-CAT		Post-CAT		Pre-CAT		Post-CAT	
	r (Spearman)	p-value	r (Spearman)	p-value	r (Spearman)	p-value	r (Spearman)	p-value
PSI								
MCC RE (Relation S/N zero)	0.23643	0.6097	0.20597	0.6577	0.61237	0.1438	**	**
MCC LE (Relation S/N zero)	0.0000	1.0000	0.51493	0.2370	0.75724*	0.0487	-0.40825	0.3632
MCC RE (Relation S/N -40)	-0.39406	0.3817	0.15954	0.7326*	0.31623	0.4896	**	**
MCC LE (Relation S/N -40)	0.70412*	0.2342	**	**	0.57735*	0.1747	0.31623	0.4896
MCI RE (Relation S/N zero)	0.3706	0.9371	0.20597	0.6577	0.15811	0.7349	0.15811	0.7349
MCI LE (Relation S/N zero)	0.23424	0.6132	0.51493	0.2370	0.31623	0.4896	0.40825	0.3632
MCI RE (Relation S/N -15)	-0.35465	0.4351	0.87386*	0.0101	0.54006*	0.2108	0.11952	0.7985
MCI LE (Relation S/N -15)	0.07881	0.8666	0.0000	1.0000	0.41833	0.3503	0.44544	0.3165
NVDT								
DE RE	0.57660	0.1754	0.20000	0.6672	0.32434	0.4779	-0.18356	0.6936
DE LE	0.14415	0.7578	-0.12060	0.7967	0.16217	0.7283	-0.47809	0.2779
RGDT	0.70000	0.1881	-0.77143*	0.0724	0.0000	1.0000	0.80000	0.1041

*Significant values (p<0.05) – Spearman's correlation coefficient (r), considering r = 0 to 0.25: very weak; 0.25 to 0.50: weak; 0.5 to 0.75: moderate; 0.75 to 0.9: strong and, 0.9 to 1: very strong

** All values of the variables were the same, not being possible to compute the correlation between them

Subtitle: CAT = computerized auditory training; PSI = Pediatric Speech Intelligibility; S/N = sinal noise; RGDT = Random Gap Detection Test; NVDT = Nonverbal Dichotic Test; MCC = contralateral competitive message; MCI = ipsilateral competitive message; RE = right ear; LE = left ear; DE = directed attention

this study to perceive aurally acoustic differences due time[23], is directly related to immaturity in the perception of phonic speech contrasts, especially in children of the group with PD associated to the APD. There is no possible explanation for the fact that the temporal resolution inability does not result in atypical phonological development in the children of G1. It is highlighted, however, that the temporal resolution ability is one of the factors responsible for the typical phonological acquisition, but, it should not be considered in its singularity. Other aspects should be considered in this analysis, as the environment in which the child is inserted, types of exhibition to language, encouraging appropriate development, family history, among others. All these aspects were not analyzed in this study, since they were not characterized as a goal.

The hearing ability of figure-ground for verbal sounds (PSI test) was rehabilitated in those children who had pre-CAT alteration. It is important to mention that the entire sample reached the maximum score of correct answers in the revaluation, considering such skill (Table 1). These findings show that the CAT done through *Escuta Ativa* software enabled new learning for the children who had alteration and maintained the ability in those with pre-intervention normality. However, there was no significant difference, once most pre-CAT children already presented the exam within normality.

Regarding the performance in different conditions of auditory competition, in G1 pre-CAT, unlike what is reported in the literature[17], children presented better performance when the competition level was higher (presented noise with intensity above the sentence presentation) and in the right ear. It is believed that this fact has occurred due to self-learning, once the same phrases are displayed in each step repeatedly. Moreover, when the level of difficulty was higher, the children were again instructed to pay attention to the fact that the noise would be in greater intensity to the sentence, which may have aroused greater challenge, attention and concentration in the activity, improving the performance. It is also highlighted that the superior result in the right ear shows activation of the left hemisphere, responsible for language, agreeing to the test, since it is an evaluation with use of verbal stimuli.

The best performance in the MCI stage, when comparing with the MCC, was not an expected finding for the study, because it is known about the higher level of difficulty in the MCI stage, in which the stimulation is unilateral. However, the data is important, since it showed better performance and ability of children in responses, without binaural separation. The binaural separation ability depends on the subject to be able to attend and make the integration of sound stimuli received from both ears, simultaneously[1], and separate them. The children in this study had no better performance in the ability of separation but in the selective attention, which requires that the subject can select a main sound stimulus in the presence of competitive stimulus, being both skills evaluated with unilateral presentation (MCI step). Both binaural separation and selective attention are related to auditory figure-ground skill[8]. It is believed that this finding is justified because the binaural separation requires greater demand in the auditory pathways, since it needs to perform integration of more processes with sounds from different ears.

A previous study[4] carried out in children with speech alteration showed that the PSI test in contralateral competitive message was not sensitive enough to identify alteration in this population, because the children did not present errors during the evaluation. According to the authors, this result may be related to the fact that the message is shown on one side and the phrase on another, each ear receiving verbal stimulus monoaurally[4]. Despite the knowledge that the difficulty in the PSI test may be associated with lack of awareness of phonemes that compose the speech[18], this test was the one that showed the least significant results in intragroup and intergroup comparison, as well as pre-CAT changes.

It was considered only the directed hearing stage in the NVDT, because the assessed children presented normality in the free hearing stage. However, in the guided hearing stage, even if the result was not significant, G1 children showed greater change. This step relates itself to the sustained attention ability, in which the child needs to maintain attention for longer in the message coming from only one ear. Therefore, it is assumed that major difficulties in attention skills in the studied population are directly related to their reduced ability to maintain sustained attention, since it is an easily distracted population by external events. Students in schools that have acoustically inadequate classrooms may present difficulty in concentrating and, consequently, learning[24].

When comparing pre- CAT and post-CAT, it was possible to note that there was greater hits symmetry between the ears in PSI tests, after therapeutic intervention, in both groups (Table 1). This finding suggests that the effect of compensation occurred between the ears, as a result of learning generated by auditory stimulation and the possible largest network of neural connections. According to authors, the stimulation approach through auditory training improves neural circuits, with greater participation of neurons, alteration on the neural synchrony and more synaptic connections[1,13,14,15]. This improvement can be confirmed by means of behavioral tests, comparing the subject with himself/herself and reaffirms the effect of plasticity in the central nervous system, capable of generating new connections, observed in all selected tests for this study.

In addition, confirming the effect of plasticity, there was adaptation of auditory abilities in 11 children in the ability of temporal resolution, in 11 in figure-ground skill for verbal stimuli and in eight in the figure-ground ability for non-verbal stimuli. Moreover, it was noted improvement on the temporal resolution skills in three children and on figure-ground ability for non-verbal stimuli in six.

Given the obtained results, it was elaborated a table with the main published studies, that show the effectiveness of the CAT

software use in children, aiming a clearer and more didactic presentation of these findings (Chart 2).

As for the findings of Scale of Auditory Behaviors (SAB), there was a significant result in the analysis of scores between the groups, pre-CAT and post-CAT, indicating that the intervention produced functional auditory changes, perceived by parents/guardians (Table 2). It is noteworthy that the G2 showed higher scores, on this scale, on both moments of evaluation, while the G1 showed greater change in pre-CAT and post-CAT score. It was not expected that the children with APD and atypical phonological acquisition presented higher scores in the SAB. Despite the 4 months difference in the age average between the groups, being superior for G2, it is believed that this factor was not decisive for better performance on the scale. However, the hypothesis is that these results suggest that eventual daily difficulties related to auditory skills were not perceived clearly by the parents/guardians of children in G2, since the focus of attention was facing, possibly, phonological change.

Authors report that there is a need for studies on the use of scales that measure the auditory behavior in young children, as in the current study[11]. The SAB Scale was designed to be

Chart 2. Researches with software for auditory training and measuring od training for behavioral evaluation, in children with auditory processing disorder or alteration of language or speech, in the last six years

Author(s)	Sample	Used software	Number of sessions	Results
Martins; Pinheiro; Blasi (2008)[13]	Two 9 years old children with diagnosed APD	Pedro in the haunted house	Eight sessions, once a week	Adequaccy of auditory skills of figure-ground for verbal and non verbal sounds, temporal resolution and temporal ordination.
Balen; Massignani; Schillo (2008)[25]	Three children (from 9 to 14 years old) with diagnosed APD	Fast ForWord	40 sessions, 5 days a week	There was improvement in only two children and also not interest for the software.
Pinheiro; Capellini (2009)[24]	40 children with learning difficulty	Audio Training	18 sessions, twice a week	Superior performance in changed auditory skills, in children Who had CAT.
Pinheiro; Capellini (2010)[26]	40 children with learning difficulty	Audio Training	18 sessions, twice a week	Children with learning difficulty presented worse performance on phonological and auditory tasks, when compared with the normal learning process.
Comerlatto Junior; Silva; Balen (2010)[14]	18 children with APD	Assistant in Hearing Disorders Rehabilitation Software (SARDA)	Approximately 12 sessions, three times a week	There was an improvement only in temporal resolution ability, with no difference in the standard frequency and duration tests.
Cameron; Dillon (2011)[27]	Nine children aged between 6 and 11 years, identified by teachers with abnormal auditory behavior, confirmed after behavioral assessment	LiSN & Learn auditory training software	60 sessions, five times a week	There was improvement in hearing skills, as well as behavioral changes, reported by parents and children themselves.
Cameron; Glyde; Dillon (2012)[28]	Tem children aged between 6 and 9 years and 9 months, with APD	LiSN & Learn auditory training software or Earobics	84 daily sessions of 15 minutes	There were behavioral improvement reports with both CAT procedures. However, there was an improvement in the spatial location ability only in the group receiving therapy with LISN & Learn software.
Cameron et al. (2014)[29]	144 indigenous children from Australia, between 6 and 12 years old, evaluated regarding spatial processing ability. Ten presented changes and nine made CAT	LiSN & Learn auditory training software	Approximately 35 sessions, five days a week	There was a correlation between the number of sessions and the improvement of performance in LISN-S tests and improvement in spatial ability.
Murphy et al. (2015)[22]	17 children with speech alteration	System for testing auditory responses-STAR	12 sessions, twice a week	There was no improvement in phonological skills.

Subtitle: APD = auditory processing disorder; CAT = computerized auditory training

used by teachers or parents, in order to identify hearing impairment in the child and appropriate referral[11]. In this research, the scale has proved to be an interesting tool for measuring the therapeutic efficacy to be used on the clinic and its use is recommended as routine, as, in the present study, such method allowed understanding of auditory functioning of children, in addition to be driven, in a personal and unique way, the dialogue with parents/guardians. It is emphasized also the importance of disclosure of this material to teachers, considering that this protocol was developed considering this population and parents, to avoid late identification and intervention of APD in students.

The findings of the current research demonstrated a positive correlation between the SAB scale and some conditions of the selected tests only pre-CAT (Table 3). In the consulted literature, a study found the correlation between the SAB scale and eight behavioral tests of AP (different from those analyzed in the present study), in Portuguese children in public schools aged from 10 to 14 years incomplete. The authors observed a positive relationship between the measures, which means, the higher the score on the SAB scale, the greater the number of hits in behavioral tests[11].

In the present study, it was also verified a correlation between the SAB scale and the behavioral tests in group performance analysis, demonstrating positive relationship MCC stage in the left ear (relation -40 dB) and in G1 group and PSI at different stages of competition, in G2 group, pre-CAT. In the post-CAT analysis, there was a positive correlation MCI stage in the right ear (relation -15 dB) and negative in RGDT test only for the G1 group (Table 4). The fact that RGDT test present negative correlation with SAB scale after CAT was expected, because, the lower the value in milliseconds of gaps perception by the subject in the test, the greater should be the score on the scale. Remembering that, the higher the score, the better is the auditory behavior, except in RGDT test. It is understood that these correlations are reliable, because the fact that MCC was worse than expected does not diminish the importance of the finding, which were the information of best performance of children with unilateral stimulation, at the expense of binaural stimulation. Researchers[30] verified the relationship between performance in dichotic behavioral tests, monotic and temporal applied in children and young people from 6 to 16 years old with APD complaints, as well as performance in SAB scale in its application with the parents or guardians, finding correlation between the scale and behavioral tests, mainly in the temporal tests.

It must be observed the scarcity of published studies about the use of SAB scale. In order to illustrate the use of this scale in monitoring the effect provided by the CAT, in this study, it is mentioned mother and grandmother reports of two children, respectively, "*'he is reading more, now he wants to read*" and "*the TV volume did not turn down, but if you go there and turn it down, he does not turn up as before"*. Issues related to behavioral changes observed by teachers in the classroom were also exposed by most mothers, regarding the improvement in attention and, consequently, better school performance. These statements reinforce the effects of therapeutic intervention in the auditory, social and school behavior of the child.

CONCLUSION

The CAT with the use of *Escuta Ativa* software showed itself effective to improve the gnosis processes of school children with typical and atypical phonological acquisition and, in some cases, even adapted such processes. There was a correlation between the behavioral tests and the score in the SAB.

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