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# Auditory training in autism spectrum disorder: a case report

## Treinamento auditivo no transtorno do espectro autista: relato de caso

### ABSTRACT

This study aimed to measure the effects of a Computer-based Auditory Training Program (CBATP) on an adolescent diagnosed with Autism Spectrum Disorder (ASD) and Central Auditory Processing Disorder (CAPD). This is the case report of a male, 14-year-old adolescent diagnosed with ASD. The individual was submitted to basic audiological evaluation, central auditory processing assessment and hearing electrophysiology (EP), pre- and post-therapeutic intervention. Central auditory processing (CAP) was assessed by means of the following instruments: Time-compressed Speech Test (TCST), Random Gap Detection Test (RGDT), Staggered Spondaic Word Test (SSWT), Frequency (Pitch) Pattern Sequence Test (FPST), and Duration Pattern Test (DPT). The P300 component of the Event-related Potential (ERP) was used in the hearing EP. Pre-intervention assessment of CAP showed changes in the auditory skills of closure, figure-ground and temporal ordering, but normal temporal resolution ability. Post-intervention evaluation of CAP showed improvement in all previously mentioned auditory skills, except for the figure-ground ability, which remained unchanged. Regarding the findings of the hearing EP, a decrease in the latency of the P300 component was observed pre- and post-intervention. This study demonstrated that the use of a CBATP resulted in improvement in the hearing abilities assessed in an adolescent diagnosed with ASD.

### RESUMO

O objetivo deste estudo foi mensurar o efeito do treinamento auditivo computadorizado em um adolescente diagnosticado com Transtorno do Espectro Autista e Transtorno do Processamento Auditivo. Participou do estudo um adolescente de 14 anos, do sexo masculino, diagnosticado com Transtorno do Espectro Autista. O sujeito foi submetido à avaliação audiológica básica, avaliação do processamento auditivo central e avaliação eletrofisiológica da audição pré e pós-intervenção. A avaliação do processamento auditivo foi composta do Teste de Fala Comprimida (FC), Randon Gap Detection Test (RGDT), Staggered Spondaic Words (SSW), Teste de Padrão de Frequência (TPF) e Teste de Padrão de Duração (TPD). Na avaliação eletrofisiológica, utilizou-se o Potencial Evocado Auditivo Cognitivo (P300). Na avaliação do processamento auditivo central pré-intervenção terapêutica, observou-se alteração nas habilidades de fechamento auditivo, figura-fundo e ordenação temporal. Na habilidade auditiva de resolução temporal, o sujeito da pesquisa demonstrou desempenho dentro dos padrões de normalidade. Na realização do processamento auditivo central, foi possível observar melhora nos resultados de todas as habilidades auditivas citadas anteriormente, exceto na habilidade de figura-fundo, que permaneceu alterada. Quanto aos achados da avaliação eletrofisiológica da audição, verificou-se diminuição da latência do componente P300 na comparação dos resultados pré e pós-treinamento auditivo. Este estudo demonstrou que a utilização de treinamento auditivo trouxe como efeito uma melhora das habilidades auditivas avaliadas de um adolescente diagnosticado com Transtorno do Espectro Autista.

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## INTRODUCTION

Autism Spectrum Disorder (ASD) is characterized by difficulty in social interaction and communicative skills. Individuals with ASD may show physical or visual discomfort, delay or absence in verbal and gestural language, few responses to sound stimuli, and difficulties in accepting changes, mainly in routine activities. In addition, they may present repetitive, restricted and stereotyped behaviors<sup>(1)</sup>.

Considering the difficulties in communicative abilities and the perceptual disturbances associated with the condition, individuals with ASD may present changes in auditory skills. Thus, this population may show low performance in the processing of acoustic information in the auditory Central Nervous System (CNS), resulting in Central Auditory Processing Disorder (CAPD)<sup>(2,3)</sup>. It should be emphasized that such auditory changes result in damages in both language acquisition and its functional use.

The P300 component of the Event-related Potential (ERP) is an objective, non-invasive tool that assists with understanding aspects related to Central Auditory Processing (CAP). In this context, there is evidence that individuals diagnosed with ASD present changes in the register of ERP suggestive of damage to the auditory pathway at the cortical level<sup>(4-6)</sup>.

In the literature, studies including individuals with ASD and CAPD only address the process of audiological diagnosis, and no studies with therapeutic intervention proposals involving different auditory abilities for these cases have been found. Thus, a Computer-based Auditory Training Program (CBATP) can be a motivating and effective therapeutic intervention for the rehabilitation of impaired auditory skills.

In this context, this study aimed to measure the effects of a CBATP on an adolescent diagnosed with ASD and CAPD through behavioral and electrophysiological assessments performed pre- and post-therapeutic intervention.

### Clinical case presentation

This longitudinal, quantitative, clinical case report was approved by the Research Ethics Committee of the aforementioned Institution under protocol no. 81117517.0.0000.5346. The adolescent's legal guardian signed an Informed Consent Form (ICF) and the researchers signed a Non-disclosure Agreement (NDA) prior to study commencement. All ethical and moral procedures were respected as foreseen in Resolution 466 of 2012 of the National Health Council.

Five individuals diagnosed with ASD were invited to participate in the study. In order to compose the sample, individuals should meet the following inclusion criteria: present hearing within normality patterns<sup>15</sup>, diagnosis of ASD performed by a multidisciplinary team, classified according to Diagnostic and Statistical Manual of Mental Disorders (DSM-V) criteria; impairment in at least one auditory ability, evaluated by behavioral tests of the CAP; behavioral conditions to participate in the study.

After analysis of the aforementioned criteria, four individuals were excluded because they did not present behavioral and emotional conditions to participate in the therapeutic intervention

of the research. Thus, only one male, 14-year-old individual was included in the present case report.

The individual was diagnosed with ASD at the age of 13 by a neurologist and an interdisciplinary team. The request for complementary evaluations, which enabled the diagnosis, was made by the board of the school attended by the adolescent, motivated by his teachers' observations about his behavior. The adolescent received a late diagnosis and was referred by the psychologist to speech therapy at age 14 due to complaints associated with auditory processing. During the speech-language evaluations and the data collection procedure, it was observed that the adolescent was sometimes inattentive and easily dispersed; however, he was very collaborative to the requests of the evaluators and/or therapist, and presented reliable results in the assessments. These observed behaviors were consistent with the reports by his teachers and mother. In addition, he did not present any general health problems.

It should be emphasized that the evaluation and reassessment procedures were performed by two different speech-language pathologists, both with experience in the area, and the therapeutic sessions of auditory training were conducted by two other speech therapists. This evidences a methodological concern and characterizes this case study as double-blind.

Initially, anamnesis was conducted with the adolescent's caregiver, and then the individual underwent assessment of Pure-tone Threshold Audiometry (PTA), Tympanometry, and Acoustic Reflex Threshold (ART). In addition, the Scale of Auditory Behaviors (SAB) was applied. The SAB questionnaire was composed of twelve questions classified into four subareas: selective/focused attention, organizational capacity, reading comprehension, and academic performance<sup>(7)</sup>.

After the questionnaire, the individual was submitted to behavioral evaluation of CAP. For this evaluation, the following instruments were selected: Time-compressed Speech Test (TCST)<sup>(8)</sup>, Staggered Spondaic Word Test (SSWT) in Portuguese<sup>(9)</sup>; Random Gap Detection Test (RGDT)<sup>(10)</sup>; Frequency (Pitch) Pattern Sequence Test (FPST)<sup>(11)</sup>, and Duration Pattern Test (DPT)<sup>(11)</sup>. Thus, the auditory abilities of closure, figure-ground for verbal sounds, temporal resolution, and temporal ordering were evaluated.

All tests were presented binaurally at an intensity of 50 dB SL above the tritonal mean. In the TCST, the stimuli were delivered monaurally. In this evaluation, the patient heard a list of 50 words compressed using the electromechanical time process. Monosyllabic or disyllabic words were used, and the patient responded according to his own understanding.

The SSWT was performed in dichotic listening, with presentation of 40 items, two words in each ear, partially overlapping. The test consisted of four steps: non-competitive right, left competitive, right competitive, and non-competitive left. The patient was instructed to respond to the exact order in which the words were presented. For the RGDT, pure tones were presented in the frequency range of 500 to 4000 Hz in time intervals ranging from zero to 40 ms. The individual was instructed to listen to the tones presented and answer how many

whistles occurred, which could be one or two. In the FPST, the stimuli were composed of three tones, differing between low (880 Hz) or high (1122 Hz) frequency. In each sequence, two equal tones and one different tone were presented.

As for the DPT, the stimuli were composed of three tones of 1000 Hz, differing by duration: 250 ms for short tones and 500 ms for long tones. Each sequence had two tones of equal duration and one different tone. For both the FPST and the DPT, the individual listened to the tones and was instructed to respond by naming which sequence was presented.

After the CAP behavioral battery, the participant was submitted to hearing electrophysiology (EP) of the ERP using a 2-channel diagnosis device (Intelligent Hearing Systems - IHS®). During the EP, the individual remained seated in an armchair in a quiet room, and had his skin cleaned with abrasive paste (Nuprep®). Disposable surface electrodes positioned at specific spots were used: the active electrode (Cz) was placed at the cranial vertex and connected to channels A and B, at the positive input of the preamplifier; the ground electrode (Fpz) was placed on the forehead; the reference electrodes were placed in positions M1 (right mastoid) and M2 (left mastoid) and connected to channels A and B, at the negative input of the preamplifier, respectively. The stimuli were presented binaurally using insertion phones at a fixed intensity level of 80 dBnHL. Impedance was maintained between 1 and 3 kohms. There were 300 stimuli, of which 240 were frequent (/ba/) and 60 were deviant (/di/), according to the Oddball paradigm. For the register of the ERP, the individual was instructed to pay attention only to the deviant stimuli. Only 10% of artifacts were considered.

Marking of the traces was performed by a speech-language pathologist with theoretical-practical expertise in hearing EP. The P300 component of the ERP was marked in the tracing of deviant stimuli. For the markers, the parameters of a study conducted with children with typical development using the same equipment were considered<sup>(12)</sup>. In the P300 amplitude marking, the instructions in the IHS® device manual were followed, and potential was determined considering the amplitude of the peak to the next valley.

It is worth noting that the evaluations were carried out in two 40-min sessions, scheduled in advance with the caregiver.

After completion of the previously described assessments, the therapeutic intervention was started: 16 individual, 30-40 min sessions held three times a week.

The Computer-based Auditory Training Program (CBATP) was used as training model, and the *Escuta Ativa* software chosen was due to the individual's profile.

The *Escuta Ativa* software comprises 12 tasks whose goal is to improve auditory processing skills. Sound intensity was adjusted and calibrated with pure tones and words at levels defined as comfortable by the individual. Then an individual profile was created based on the responses obtained through the application of a self-assessment questionnaire, speech-in-noise test, identification of whistles, and dichotic listening test

using the software. A supra-auricular headphone (Sony MDR-XB450AP) was used and auditory training was started.

One activity was held per session, and it followed the sequence proposed by the software, in addition to progressing at the four levels of difficulty: easy, medium, difficult and insane, respectively, according to the success in the activities. It should be emphasized that both the sequence and advance in the level of difficulty of the tasks are automatic data of the software. The skills to be stimulated were presented in the following order: duration pattern; frequency pattern; temporal resolution; temporal ordering; detection and discrimination; association and auditory memory of nonverbal sounds; recognition and auditory closure; binaural separation; binaural integration; location; attention. It is worth noting that the chosen software presents only 12 tasks; therefore, extra sessions were conducted with tasks that contemplated the auditory figure-ground and closure abilities, in which the individual presented more difficulties.

Descriptive data analysis was performed to compare the pre- and post-CBATP assessment results.

After the 16 sessions of therapeutic intervention, the adolescent was once again submitted to application of the SAB questionnaire, CAP behavioral battery, and hearing EP (P300 component of the ERP). This post-CBATP assessment aimed to measure the effects of training model on the individual of this research. It should be noted that the reassessment included the same procedures previously listed for the pre-therapeutic intervention.

Regarding the SAB questionnaire, a score of 31 points was found in the pre-CBATP evaluation, indicating need for referral to CAP assessment. It is worth noting that the behaviors regarding the items "Does not understand well when someone speaks fast or muffled", "Difficulty following oral instructions", "Asks to repeat the words", "Easily distracted", and "Disorganized" were reported as frequent actions. However, in the post-CBATP, the score increased from 31 to 43 points. Thus, this reassessment indicated auditory behavior expected for children with typical development and demonstrated that there was an improvement in auditory behavior in daily life situations, especially in the aforementioned SAB items.

In the pre-CBATP evaluation, values below the reference standards were observed for TCST, SSWT, FPST, and DPT, indicating changes in the auditory skills of closure, figure-ground, and temporal ordering. However, in the RGDT test, the individual showed performance within the normality standards, with no impairment in the auditory ability of temporal resolution. Findings of the CAP behavioral battery showed improved results in all the aforementioned auditory abilities except for the figure-ground skill, which remained altered. Table 1 presents the results of the behavioral evaluation pre-and post-CBATP.

In the hearing EP, the P300 component of the ERP showed increased latency at the pre-therapeutic intervention evaluation; however, this value decreased at the post-intervention assessment as an effect of the auditory training, evidencing results close to the reference values proposed in the literature (Table 2).

**Table 1.** Results of the behavioral evaluation pre-and post-Computer-based Auditory Training Program (CBATP)

<b>Time-compressed Speech Test (TCST)</b>			
<b>% correct responses</b>	Pre-CBATP	Post-CBATP	Reference values
<b>RE</b>	72	98	92% B <sup>(8)</sup>
<b>LE</b>	68	92	
<b>Staggered Spondaic Word Test (SSWT)</b>			
<b>% correct responses</b>	Pre-CBATP	Post-CBATP	Reference values
<b>RE</b>	27.5	62.5	≥90% B <sup>(9)</sup>
<b>LE</b>	72.5	75	
<b>Random Gap Detection Test (RGDT)</b>			
<b>Average</b>	Pre-CBATP	Post-CBATP	Reference values
	8 ms	4 ms	Up to 10 ms <sup>(10)</sup>
<b>Frequency (Pitch) Pattern Sequence Test (FPT)</b>			
<b>% Hits</b>	Pre-CBATP	Post-CBATP	Reference values
	75	88.33	76% <sup>(11)</sup>
<b>Duration Pattern Test (DPT)</b>			
<b>% Hits</b>	Pre-CBATP	Post-CBATP	Reference values
	53.33	76.33	67% <sup>(11)</sup>

**Captions:** RE: right ear; LE: left ear; %: percentage; B: both ears; CBATP: Computer-based Auditory Training Program

**Table 2.** Results of the P300 component of the Event-related Potential (ERP) pre- and post-Computer-based Auditory Training Program (CBATP)

<b>Component Event-related Potential (ERP)</b>					
	<b>Latency (ms)</b>		<b>Latency (ms)</b>		<b>Reference values<sup>(12)</sup></b>
	<b>Pre-CBATP</b>		<b>Post-CBATP</b>		
	RE	LE	RE	LE	
<b>P300</b>	361	368	335	325	347.25
	<b>Amplitude (μV)</b>		<b>Amplitude (μV)</b>		<b>Reference values<sup>(12)</sup></b>
	<b>Pre-CBATP</b>		<b>Post-CBATP</b>		
	RE	LE	RE	LE	
<b>P300</b>	3.05	2.70	3.80	4.94	7.44

**Captions:** RE: right ear; LE: left ear; CBATP: Computer-based Auditory Training Program

## DISCUSSION

Results of the present study showed improvement in the auditory performance of the individual assessed after the Computer-based Auditory Training Program (CBATP). The effectiveness of this training model has already been demonstrated through the use of behavioral evaluations of the Central Auditory Processing (CAP) and hearing electrophysiology (EP) in different populations. However, there is only one study<sup>(2)</sup> in the literature, recently published, involving individuals with Autism Spectrum Disorder (ASD) associated with Central Auditory Processing Disorder (CAPD) addressing therapeutic intervention.

In this study, the authors performed auditory processing evaluation including figure-ground and closure tests, as well as a test to measure the language level of three individuals aged 10-12 years, and compared the pre- and post-training results. The aforementioned study verified improvement in the results of the tests performed after the therapeutic intervention. The scarcity of studies conducted with this population is possibly justified because these individuals lack conditions for the realization of therapeutic intervention using the auditory training approach. However, the adolescent of the present study presented medical and psychological evaluation stating that he was emotionally and physically able to carry out the proposed intervention.

In addition, the individual's conditioning capacity to undergo the CBATP was verified during the speech-language pathology assessments.

Results obtained with application the Scale of Auditory Behavior (SAB) showed that the individual of this study presented positive functional changes perceived by the caregiver, that is, increased questionnaire scores after the CBATP. As with other populations, in cases with ASD, the SAB also proved to be an efficient instrument in measuring an auditory therapeutic intervention.

A previous research showed that there is a strong relationship between SAB scores and behavioral CAP tests, and that this questionnaire can be used in cases of CAP screening. This is because the researchers found that the higher the scores in the questionnaire, the better the performance in the behavioral evaluations of the CAP<sup>(7)</sup>. In addition, self-assessment questionnaires are an objective and rapid way to measure the perception of leaders, teachers, or the individuals themselves in the face of their difficulties. In this context, it is suggested that, in cases in which it is not possible to perform a battery of CAP behavioral tests in patients with ASD due to lack of condition or other pertinent matter, the SAB questionnaire should at least be applied to the individuals' parents/guardians and/or teachers, so that data for appropriate referrals and proposals

for therapeutic intervention can be generated, in addition to measurement of the results.

Auditory skills allow individuals to assimilate in an appropriate and efficient manner the auditory information received. For this phenomenon to occur, it is essential that the Central Nervous System (CNS) be healthy and well developed. A study addressing evaluating this population demonstrated greater excitability of the cortical neuron in response to sound stimuli, suggesting that cortical responses to repeated sounds may characterize abnormal habituation<sup>(13)</sup>. Thus, it can be inferred that this population presents changes in the auditory abilities.

The performance in the CAP behavioral evaluations pre-CBATP shown in Table 1 indicates that the individual with ASD presents changes in the auditory skills of closure, figure-ground, and temporal ordering. These results reveal a disorder of the auditory processing. As previously mentioned, other studies have reported impairment in the auditory abilities in this population, corroborating the findings of the present study<sup>(3)</sup>. Also, one relevant parameter is that other surveys have reported that the most noticeable changes in this population occur in the skills of figure-background, closure, and temporal ordering<sup>(2,3)</sup>.

In view of these findings, it was observed that the temporal resolution ability was not altered at the pre-CBATP evaluation, although it improved after the therapeutic intervention.

Post-intervention results demonstrated the effects of the CBATP on the auditory abilities. However, the only auditory skill that did not show performance within normality post-intervention was figure-ground, which was evaluated through the Staggered Spondaic Word Test (SSWT). This test has a strong relationship with the language levels of individuals and, therefore, the areas of greater CNS dysfunction in individuals with ASD are also associated. Nevertheless, since the objective of this research was not to correlate the level of the auditory abilities with the language levels, these data cannot be scientifically verified.

Regarding the register of the ERP at the pre-CBATP, the individual of the research showed increased latency of the P300 component compared with that of children with typical development (Table 2)<sup>(12)</sup>. Other studies corroborate this result and report that individuals diagnosed with ASD present increased latency of the P300 component, as well as the absence of this potential in some cases<sup>(4-6)</sup>. Such findings may indicate changes in the register, storage, and processing of auditory information; suggesting impairment of the auditory pathway at the cortical level.

With respect to the findings associated with the P300 component post-CBATP (Table 2), the adolescent showed latency values of the P300 component within normality, corroborating the findings of a study conducted with children with typical development that used the same parameters of stimulus and registration of this potential<sup>(12)</sup>. Considering the increase in the P300 latency value after the proposed therapeutic intervention, this result indicates physiological changes in the auditory cortex. Such data demonstrate that, as in other populations, the CBATP also provided improvement in the ability of auditory discrimination and in the auditory CNS of an individual with ASD.

Another issue to be highlighted is that no studies presenting results of Long-latency Auditory Evoked Potentials (LLAEP)

before a therapeutic intervention with the population under study have been found in the literature.

There is scientific evidence that a CBATP influences the school and social performance of individuals and that, in addition to improving auditory skills, it can improve in the academic performance of children with learning difficulties<sup>(14)</sup>. In this context, it is important to highlight that individuals diagnosed with ASD present difficulties in the school environment. A survey pointed out that the schooling process in this population is not complete, and that most of these individuals do not reach High School. Moreover, the school evasion rate of these students is extremely high<sup>(15)</sup>. Faced with this obstacle, this study brings the proposal to consider the CBATP an ally for the improvement of academic functions in this population.

It is worth emphasizing that, although this study demonstrated the efficacy of a CBATP on an individual with ASD, this training as a form of therapeutic intervention does not replace the therapy of language aspects. It is believed that the stimulation of auditory abilities, as an ally of the language therapy in individuals with ASD, can assist with the improvement of their academic, social and therapeutic skills. Altered auditory skills can limit the performance of individuals in other forms of stimulation and academic performance. Therefore, auditory skills deserve greater attention within the speech-language pathology evaluations in clinical practice.

Although satisfactory results were obtained, this study presents a limitation for being a case report and having a target population that lacked conditions to undergo the evaluations and interventions proposed.

## FINAL COMMENTS

This study demonstrated the effects of auditory training on the auditory skills of an adolescent diagnosed with Autism Spectrum Disorder (ASD) with improved results verified in the behavioral and physiological evaluations of the central auditory processing post-therapy intervention.

Considering the contributions to clinical practice, the present study extends the concept of possible therapeutic interventions in individuals with ASD, demonstrating that the action of speech-language pathologists should not be limited to diagnosis.

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### Author contributions

*LF was responsible for data analysis and writing of the article; ARD was responsible for data acquisition and writing of the article; FSP, EP and ICR were responsible for writing the article; EPVB was responsible for guiding the research.*