Original Article

https://doi.org/10.1590/2317-6431-2025-3076en

Audiology Communication Research
ISSN 2317-6431

Teleaudiology in the rehabilitation of central auditory processing disorder in adults: an analysis of the effectiveness of the intervention and user satisfaction

Teleaudiologia na reabilitação do transtorno do processamento auditivo central em adultos: uma análise da eficácia da intervenção e satisfação dos usuários

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ABSTRACT

Purpose: To verify the effectiveness of using teleaudiology in the rehabilitation of Central Auditory Processing Disorder (CAPD) and the participants' satisfaction with the treatment received. **Methods:** Pilot intervention and quantitative study in which 15 individuals of both genders, with hearing thresholds within normal limits and diagnosed with CAPD, underwent eight online sessions of musical auditory training, conducted twice a week. One month after the end of the treatment, the participants were re-evaluated using the same behavioral tests as in the initial assessment and completed a satisfaction questionnaire regarding the service and care provided. **Results:** No statistically significant differences were observed between the right and left ears for each test (p>0.05). However, a significant difference was found for the Frequency Pattern Test (FPT) test (p=0.002), and a trend toward significance was observed for the Dichotic Digit Test (DDT) in the left ear (p=0.063). When comparing results categorized as "normal" and "altered" before and after the intervention, significant improvement was noted in the DDT for the left ear (p=0.037) and a trend toward improvement in the FPT test (p=0.072). Regarding user satisfaction, the majority of participants reported being satisfied with the quality of the service and care. Moreover, 93.33% stated that the online format made it easier to undergo auditory training. **Conclusion:** Teleaudiology shows promise in the rehabilitation of CAPD. Participants expressed satisfaction with the quality of service and considered the online training format accessible.

Keywords: Auditory perceptual disorders; Hearing disorders; Neuronal plasticity; Telerehabilitation; Auditory perception

RESUMO

Objetivo: Verificar a eficácia do uso da teleaudiologia na reabilitação do transtorno do processamento auditivo central (TPAC) e a satisfação dos participantes em relação ao tratamento recebido. **Métodos:** Estudo-piloto de intervenção e quantitativo, em que 15 indivíduos de ambos os gêneros, com limiares auditivos dentro dos padrões de normalidade e com diagnóstico de TPAC foram submetidos a oito sessões de Treinamento Auditivo Musical de forma *online*, duas vezes por semana. Um mês após o término do tratamento, os indivíduos foram reavaliados com os mesmos testes comportamentais da avaliação e responderam a um questionário de satisfação em relação ao serviço e atendimento. **Resultados:** Na comparação entre orelha direita e esquerda para cada teste, não houve diferença estatisticamente significativa (p>0,05). Constatou-se diferença para o Teste Padrão de Frequência (TPF) (p=0,002) e tendência à diferença para o Teste Dicótico de Dígitos (TDD) da orelha esquerda (p=0,063). Os resultados foram comparados entre "normal" e "alterado" pré e pós-intervenção, sendo possível constatar que houve diferença para o TDD da orelha esquerda (p=0,037) e tendência à diferença para o TPF (p=0,072) após a intervenção. Quanto à satisfação dos usuários, a grande maioria se mostrou satisfeita com a qualidade do serviço e dos atendimentos; 93,33% dos participantes afirmaram que houve maior facilidade para realização do treinamento auditivo no formato *online*. **Conclusão:** A teleaudiologia é promissora na reabilitação do TPAC. Os participantes demonstraram satisfação com a qualidade do serviço e consideraram acessível o formato *online* do treinamento.

Palavras-chave: Transtornos da percepção auditiva; Transtornos da audição; Plasticidade neuronal; Telerreabilitação; Percepção auditiva

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Conflict of interests: No.
Authors' contribution: RL was responsible for study planning, data collection, writing and submission of the article; DAOM performed the statistical analysis; KGMF and FSAP contributed to the final review of the manuscript; DDD was responsible for study planning, supervision of data collection, final review and guidance.
Data Availability Statement: Research data is available in the body of the article.
Funding: None.
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Received: July 04, 2025; **Accepted:** February 03, 2026
Editor-in-Chief: Renata Mota Mamede Carvallo.
Associate Editor: Eliane Schochat.

INTRODUCTION

Central auditory processing (CAP) refers to the ability of the central auditory nervous system (CANS) to interpret sound information from the peripheral auditory system. It involves auditory skills such as detection, localization, auditory discrimination, recognition, temporal ordering and resolution, figure-ground for verbal/non-verbal sounds, auditory closure and separation, integration and binaural interaction[1].

Central auditory processing disorder (CAPD) occurs when there is an alteration in one or more auditory skills[2,3] and its rehabilitation is carried out exclusively by the speech-language pathologist[2], through auditory training (AT), which consists of a set of therapeutic strategies to improve the delayed auditory skills.

Researchers[4,5] have proven the effectiveness of AT in cases of individuals with CAPD, showing improvement in auditory skills from the measurement of the neuroplasticity of the auditory system. However, patient attendance and constant repetition of activities are fundamental for the treatment of CAPD, and it is recommended that auditory training be carried out at least twice a week[6], due to the greater likelihood of auditory changes at the central level and, consequently, behavioral changes.

In this sense, teleaudiology has been studied as a facilitating resource for public service[7,8]. This practice, mediated by information and communication technologies (ICT), encompasses a wide range of possibilities for interaction between the speech-language pathologist and the user of health services, and can address auditory assessment, diagnosis and treatment[7]. It can be practiced synchronously (in real time), asynchronously (through the sending of content) or in a hybrid way (combination of the two methods)[9].

Synchronous and asynchronous care provides an efficient solution by eliminating barriers such as travel time and cost, which contribute to making treatment accessible and continuous, regardless of where the user is located. In addition, the flexibility of schedules also facilitates adherence, as it can reduce no-shows and, consequently, user dropout[10].

Considering the recommendation that auditory training be performed at least twice a week due to the greater potential for neural plasticity, it is believed that teleaudiology can be a viable tool, given its enormous potential for overcoming the aforementioned barriers. Synchronous activities can be an important tool for the rehabilitation of the population with difficulties accessing auditory rehabilitation services. Furthermore, although auditory training is considered an effective method for the rehabilitation of APD (Auditory Processing Disorder), there is a scarcity of studies addressing the use of telerehabilitation. As it is a current tool, user satisfaction should also be investigated in order to improve the provision of services.

The use of platforms such as Musical Auditory Training (MAT) has been highlighted in interventions in adults and may be interesting for online rehabilitation, since the activities are attractive and allow immediate feedback for the individual being rehabilitated, which may favor the maintenance of auditory attention during remote access[11].

The hypothesis that guided this study was that MAT, offered through telerehabilitation, is promising in the rehabilitation of adults with APD and presupposes user satisfaction with the service offered.

Based on the above, the objective of this research was to verify the effectiveness of the use of teleaudiology in the rehabilitation of APD and the satisfaction of the participants in relation to the treatment received.

METHODS

This is a pilot intervention and quantitative study conducted at the Speech-Language Pathology Service of the Federal University of Santa Maria – SAF/UFSM and approved by the Research Ethics Committee of the same institution, under number CAAE 64696022.1.0000.5346. At the beginning of the research, all participants were briefed on the procedures and signed the Informed Consent Form (ICF).

Fifteen individuals of both genders participated in the study, recruited according to the following inclusion criteria: being between 19 and 35 years old, having hearing thresholds within normal standards[12], having a speech recognition percentage index (SRPI) equal to or greater than 92% in both ears, having a type A tympanometric curve bilaterally[13,14], having a diagnosis of APD obtained through behavioral assessment, with APD being considered the presence of an alteration in at least one of the five tests of the applied battery[3], having Brazilian Portuguese as a mother tongue, being right-handed, having access to the internet, a computer with cameras and headphone jack and availability to perform the online intervention twice a week.

Individuals with chronic tinnitus, diagnosed mental illnesses, evident cognitive impairments in the medical history, those using prescribed psychiatric medications, bilingual individuals, those with musical experience, those who had already undergone some intervention for APD (Auditory Processing Disorder), and those who, for some reason, were unable to complete the established auditory training sessions were excluded.

Sample size calculation was performed by a statistician using the G-power test. The parameters adopted were an effect size of 0.7, a test power of 80%, and a significance level of 5% for comparisons of dependent samples. Thus, the sample size (N) was set at 15 individuals.

Initially, 18 individuals were recruited. Of these, three were excluded for different reasons: use of psychiatric medication, hearing loss, and lack of availability to undergo auditory training. There were no dropouts during the process. Thus, eight female and seven male individuals participated in the study, totaling 15 subjects. The average age was 24 years (minimum: 19; maximum: 33). Regarding education, ten individuals had incomplete higher education and one had completed it; one had completed postgraduate studies and two had incomplete postgraduate studies; and one was in the final stages of completing high school.

Sample selection procedures

For sample selection, individuals were initially subjected to a brief interview about health, hearing, and main complaints related to APD, such as complaints of speech comprehension in noisy environments, inattention, both in the classroom and in other environments, and difficulty discriminating sounds. Afterwards, a visual inspection of the ear canal was performed with a *Heine* brand clinical otoscope to check for any alteration or impediment to performing the hearing tests.

Furthermore, auditory threshold testing was conducted for frequencies from 250 to 8000 Hz, along with speech audiometry and behavioral tests of central auditory processing (CAP) in an acoustically treated booth using *Telephonics* supra-aural headphones and the *Resonance* R37A equipment. Acoustic immittance measurements were performed using the Interacoustics AT35 impedance meter and TDH-39 headphones.

The Central Auditory Processing Skill Self-Perception Scale (CAPSSPS) was applied as a way to screen participants before the behavioral assessment of CAP. The scale has ten questions about different aspects of daily life and graduation, which involve CAP skills. The questionnaire was applied orally and in person, with the possibility of a yes (1 point) and no (0 points) answer. A score of 5 or more than 5 and 6 or more than 6, respectively, was considered suggestive of an alteration in auditory closure and temporal resolution skills[15]. Participants with altered results on the scale and/or with complaints of speech comprehension were submitted to the behavioral assessment of CAP.

Research procedures

Pre-intervention and one-month after the auditory training period, behavioral tests of the auditory processing system were conducted. In addition, participants also answered a satisfaction questionnaire.

Behavioral tests of central auditory processing

The tests applied were chosen to encompass different auditory skills, namely, a test for auditory closure, a test for temporal ordering, a test for temporal resolution, a test for binaural integration, and a test for binaural interaction. The tests were presented at an intensity of 50 dB HL above the tritone average of each ear. The tests applied in the evaluation and re-evaluation phase, as well as the normality criteria, are described below:

- The Gap In Noise (GIN) test was used to assess temporal resolution ability and was presented in a monaural format. It consists of 35 soundtracks, and the individual had to raise their hand whenever they heard a cut/silence in the sound. Values between 3.73 and 4.01 ms were considered normal[16].
- Dichotic Digits Test (DDT): binaural integration stage: used to assess binaural integration ability. Twenty soundtracks with four numbers were presented simultaneously, at the same intensity, two per ear. The patient had to orally name all the numbers they heard, regardless of the order. A success rate ≥95% was considered the criterion for normality[17].
- Speech-in-Noise (SR) Test: used to assess auditory closure ability. It was presented monaurally, at a signal-to-noise ratio of +10 dB. Twenty-five monosyllabic words were presented to each ear. The patient had to verbalize the word as they heard it. A rate of >70% accuracy and a difference of <20% between IPRF and SR was considered normal[17].
- Frequency Pattern Test (FPT), Auditec version (1997): used to assess temporal resolution ability for frequency and was applied binaurally. Thirty soundtracks were presented, with three sounds in each track and varying frequencies, ranging from low (880 Hz) to high (1430 Hz). After listening to a track, the individual had to report the sequence of sounds in order. The normality criterion adopted was ≥86.6%[18].
- Masking Level Difference (MLD): used to assess binaural interaction ability and was applied binaurally. It consists of 33 noise tracks in the same phase, but with different signal-to-noise ratios, with a pure tone of 500 Hz. The signal can be in two conditions: same phase in both ears or in inverted phase in one ear. For test control, there are some tracks that contain only noise, without the signal. The individual should orally answer "yes" when they heard a "whistle/sound" added to the noise and "no" when they heard only the noise. Results ≥8 dB were considered normal[18].

Online intervention

After the sample selection and research procedures, the selected individuals were given in-person guidance on auditory training and how the intervention would be conducted online.

The Zoom communication platform was used to apply the online auditory training sessions. On the day of the guidance, all individuals received *Victory* brand supra-aural headphones to connect to their electronic device (personal laptop) and enable online auditory training. In addition, they were instructed that the volume for performing the activities should be audible and comfortable, and that the training environment should be kept quiet. The assessments and guidance were carried out on a single day, prior to the auditory training.

Musical auditory training

The intervention was carried out remotely and synchronously, with Musical Auditory Training (MAT)[19] being the activity platform chosen for all participants. The activities were carried out during the application of a brief protocol of eight sessions, held twice a week, totaling one month of intervention. The sessions lasted from 40 minutes to one hour, depending on the activities proposed each day. The number of sessions was established according to the time available for completion of the research and based on the minimum foreseen by the selected literature[20].

In each session, individuals received the Zoom call link via WhatsApp or email. The lead researcher projected the screen of their electronic device (computer) displaying the MAT interface and provided the necessary instructions for conducting the session. Participants were instructed to keep their cameras and microphones on throughout the session, remain in a quiet environment, and use the headphones provided by the researchers.

During the auditory training sessions, the skills of figure-ground recognition for instrumental sounds, figure-ground recognition for sequential sounds, temporal ordering for duration, temporal ordering for frequency, temporal structuring (rhythm), auditory closure, and audiovisual memory were stimulated on an increasing scale of difficulty. The chosen protocol was applied in the same way to all participants, aiming to ensure the standardization of the intervention.

During the application of the Musical Auditory Training (MAT), the original parameters for progression of the difficulty level of the program's tasks were followed; that is, the advancement of activities only occurred when the participant achieved 70% accuracy in each task. It should be noted that, for some sessions, the activities began at a moderate level of difficulty because, based on a pilot study, it was shown that the participants considered the tasks in these sessions too easy. Thus, in order to guarantee activities with a minimum level of complexity, it was decided to start at a more advanced level of difficulty. Participants had up to three attempts to correctly identify at least seven of the ten sequences in each activity, and all were able to perform according to the established protocol.

The frequency ranges of the instrumental sounds varied from 200 to 4000 Hz, composed of the following instruments: guitar, vibraphone, piano, flute, and drum.

The monaural stimulation tasks began with the left ear, considering the greater ease of performing the tasks compared to the right ear, due to the contralateral nature of most auditory pathways and the predominance of the right hemispheric system for processing nonverbal stimuli.

The protocol used in this study can be seen in Chart 1.

After one month, participants were reassessed using the same behavioral tests applied during the initial assessment. It is important to note that the researcher who conducted the initial and reassessment of the participants did not participate in the online training. Electrophysiological tests were not used in this study to measure post-intervention changes due to the limited time available for data collection.

In addition, participants were instructed to complete a satisfaction questionnaire, developed by the study authors and sent online, in order to verify their level of satisfaction with the remote modality of auditory training. The questionnaire consisted of eight objective questions, addressing aspects such as evaluation of the service provided, perception of symptom improvement, and recommendation of the service to others. The responses were collected anonymously.

The data from the behavioral assessment and reassessment of the were tabulated in Excel spreadsheets and analyzed by a professional using SPSS software, version 23.0. Initially, the data were tested for normality using the Shapiro-Wilk test. The comparison between the right and left ears before and after the intervention for the tests, which were applied monaurally, and the intragroup comparison at both time points was performed using the Wilcoxon test. A significance level of 5% was adopted for all analyses, with a test power of 80%. The analysis of the satisfaction questionnaire responses was performed descriptively and presented as percentages.

RESULTS

In the comparison between the right and left ear for each test, before and after the intervention, no difference was observed ($p>0.05$) (Table 1). Despite this, it was decided to perform the pre- and post-intervention comparisons for each ear separately, aiming at a better interpretation of the results (Table 2).

Chart 1. Protocol of activities, initial level of difficulty, and task performed by the individual during the sessions of Musical Auditory Training

Session	Activity	Initial level	Task
1	Figure-ground for instrumental sounds	Moderate	Point with the hand opposite the trained ear and name it.
2	Figure-ground for sequential sounds	Moderate	Point with the hand opposite the trained ear and name it.
3	Directed listening	Easy	Point and name it.
4	Temporal ordering for duration	Easy	Point and name it.
5	Temporal ordering for frequency	Easy	Point and name it.
6	Rhythm	Easy	Name it.
7	Closing	Moderate	Play by singing and then pointing.
8	Audiovisual memory	1st Sequential: Easy, moderate, and difficult 2nd Reverse: Easy, moderate, and difficult	Name the colors.

Table 1. Comparison of results between the right and left ears before and after the intervention for the Dichotic Digits, Speech-in-Noise, and Gap-in-Noise tests

	Average	SD	Median	Minimum	Maximum	p-value
DDT RE pre	97.37	3.749	98.0	88	100	0.527
DDT LE pre	95.70	6.803	100.0	75.5	100	
DDT RE post	98.67	1.600	100.0	95	100	0.240
DDT LE post	99.33	1.144	100.0	97.5	100	
SIN RE pre	86.13	10.013	88	68	96	0.809
SIN LE pre	86.67	9.759	88	68	100	
SIN RE post	88.00	10.029	88	72	100	0.305
SIN LE post	89.33	9.401	92	76	100	
GIN RE pre	6.07	1.751	6	4	10	0.626
GIN LE pre	5.87	2.100	5	4	12	
GIN RE post	5.40	1.682	5	4	10	0.890
GIN LE post	5.33	1.718	5	4	10	

Applied statistical test: Wilcoxon

Subtitle: SD = standard deviation; RE = Right ear; LE = Left ear; TDD = Dichotic Digits Test; SIN = Speech in Noise; GIN = Gap In Noise; pre = Pre-intervention; post = Post-intervention

When comparing the pre- and post-intervention results for each test, a difference was observed for the FPT and a trend towards a difference for the DDT of the left ear (Table 2).

The visual representation of the averages for each test performed, before and after the intervention, can be seen in Figure 1.

The results before and after the intervention were also compared qualitatively as "normal" and "altered," and it was found that there was a difference for DDT in the left ear and a trend towards a statistically significant difference for FPT (Table 3).

Table 2. Comparison of test results applied before and after the intervention, by ear

	Average	SD	Median	Minimum	Maximum	p-value
DDT RE pre	97.37	3.749	98.0	88	100	0.310
DDT RE post	98.67	1.600	100.0	75.5	100	
DDT LE pre	95.70	6.803	100.0	95	100	**0.063**#
DDT LE post	99.33	1.144	100.0	97.5	100	
FPT pre	82.62	12.098	84.0	53	96	**0.002***
FPT post	89.01	10.602	93.3	66,6	100	
MLD pre	10.40	3.481	10	4	16	0.210
MLD post	12.07	2.576	14	7	16	
SIN RE pre	86.13	10.013	88	68	96	0.392
SIN RE post	86.67	10.029	88	68	100	
SIN LE pre	88.00	9.759	88	72	100	0.284
SIN LE post	89.33	9.401	92	76	100	
GIN RE pre	6.07	1.751	6	4	10	0.301
GIN RE post	5.87	1.682	5	4	12	
GIN LE pre	5.40	2.100	5	4	10	0.533
GIN LE post	5.33	1.718	5	4	10	

Statistical test applied: Wilcoxon; #trend towards difference; *there was a difference

Subtitle: SD = Standard deviation; RE = Right ear; LE = Left ear; DDT = Dichotic Digits Test; FPT = Frequency Pattern Test; MLD = Masking Level Difference; SIN = Speech in Noise; GIN = Gap In Noise; pre = Pre-intervention; post = Post-intervention

Figure 1. Comparison of the results of the tests applied before and after the intervention, considering the median

Subtitle: RE = Right ear; LE = Left ear; DDT = Dichotic Digits Test; FPT = Frequency Pattern Test; MLD = Masking Level Difference; SIN = Speech in Noise; GIN = Gap In Noise; pre = Pre-intervention; post = Post-intervention

Table 3. Comparison between the percentage of individuals with results classified as normal and altered for each test before and after the intervention, by ear

	Normal	Altered	p-value
DDT RE pre	86.67	13.33	0.346
DDT RE post	100	0	
DDT LE pre	66.67	33.33	**0.037***
DDT LE post	100	0	
FPT pre	53.33	46.67	**0.072***
FPT post	80	20	
MLD pre	80	20	0.424
MLD post	93.33	6.67	
SIN RE pre	86.67	13.33	0.346
SIN RE post	100	0	
SIN LE pre	93.33	6.67	1.000
SIN LE post	100	0	
GIN RE pre	20	80	1.000
GIN RE post	20	80	
GIN LE pre	20	80	0.773
GIN LE post	20	80	

Statistical test applied: Wilcoxon; *there was a difference

Subtitle: RE = Right ear; LE = Left ear; DDT = Dichotic Digits Test; FPT = Frequency Pattern Test; MLD = Masking Level Difference; SIN = Speech in Noise; GIN = Gap In Noise; pre = Pre-intervention; post = Post-intervention

Chart 2. Results of the participant satisfaction questionnaire regarding the treatment received

Questions	Responses in percentage (n=15)				
1. How would you rate the quality of the service provided?	Very good	Good	Bad	Very bad	
	93.33%	6.67%	-	-	
2. Overall, how satisfied are you with the service you received?	Extremely satisfied	Satisfied most of the time.	Dissatisfied	Extremely dissatisfied	
	93.33%	6.67%	-	-	
3. Do you feel that the auditory training offered met your needs?	Yes, all of them	Yes, most of them	Yes, the minority of them	No, I haven't noticed any improvement in my symptoms	No, I felt a worsening of symptoms
	20%	66.66%	6.67%	6.67%	-
4. If a friend, family member, or acquaintance presented the same complaints, would you recommend our research to them?	Definitely yes	I think so	I don't think so	Definitely not	
	86.67%	13.33%	-	-	
5. Have you noticed an improvement in your attention span?	Yes, most of the time	Yes, at times	No, not at all	No, I realized it got worse	
	33.33%	60%	6.67%	-	
6. Answer this question if you had difficulty understanding people in noisy environments:	Yes, significantly	Yes, partially	No, nothing has changed	No, my understanding has worsened	1 participant did not respond
Did you feel your understanding improved?	28.57%	50%	14.29%	7.14%	
7. Regarding telehealth services, do you think that providing the service remotely facilitated the completion of auditory training?	Definitely yes	I think so	I don't think so	Definitely not	
	80%	13.33%	6.67%	-	
8. If you needed our services again, would you contact us?	Definitely yes	I think so	I don't think so	Definitely not	
	86.67%	13.33%	-	-	

Subtitle: % = percentage; n = number; - = no answer

Regarding user satisfaction, 93.33% were satisfied with the quality of service and customer service, 86.66% reported that most of their needs were met with MAT, and 86.67% stated with certainty that they would return to the service if necessary and recommend it to others. Regarding telephone support, 93.33% of participants stated that it was easier to complete auditory training (Chart 2).

DISCUSSION

This research is in line with the reality of telehealth, considering that after the COVID-19 pandemic many services began offering remote assistance. The main findings of this study suggested promising effects of MAT, evidenced by the improvement in temporal and partial figure-ground ordering skills.

In this study, we opted to compare the results obtained between the right ear and the left ear. Statistical analysis showed no difference between the ears before and after the intervention, which ensured data homogeneity and reinforced the promising results verified in the intragroup comparisons before and after the intervention for the analysis of each ear. Previous studies[21] also opted to perform the analyses separately for each ear. Analyzing the results for each ear separately is important for behavioral tests of central auditory processing, since there are issues to be considered, such as hemispheric dominance for verbal and nonverbal stimuli, a fact that may justify different performances between the right and left ears[22].

The pre- and post-intervention results were significant for the Frequency Pattern Test, related to temporal ordering ability for frequency, considering the percentage of responses obtained as promising regarding the classification as "normal" and "altered" pre- and post-intervention. Other researchers investigated musicians and non-musicians using the FPT, with the same version used in the present study, and the results indicate that musicians showed better performance on the test compared to the control group. This is justified by a greater perception in frequency discrimination, a fact evidenced by musical practice[23], considered as a form of auditory training by the authors of the study. This fact reinforces that the use of MAT is promising for improving central auditory plasticity for temporal ordering aspects.

The DDT test in the left ear, related to figure-ground ability for verbal sounds, obtained a result that indicated a tendency towards a difference in the comparison of the percentage of correct answers pre- and post-intervention. However, when comparing the results between "normal" and "altered," a difference was found in the two evaluation moments. The literature states that contralateral auditory fibers are more numerous, giving the right ear a greater advantage in verbal processing, since the left hemisphere has a dominant predominance for linguistic functions. The right hemisphere processes most of the auditory information coming from the left ear and is responsible for decoding musical and non-verbal sounds[22].

Therefore, it is believed that the results obtained were better only for the DDT test in the left ear, since the auditory training carried out in this research used musical stimuli, and not linguistic ones, which may have favored the plasticity of the right hemisphere, responsible for this type of decoding. Furthermore, confirming this fact, a study carried out with children with central auditory processing disorder showed that the right ear obtained better results with the use of verbal stimuli for evaluation, reinforcing the activation of the left hemisphere for verbal decoding[24]. Thus, it is believed that if verbal stimuli had been applied in the auditory training, there would also have been modifications for the DDT of the right ear. It should be noted that, in this study, all subjects were right-handed, which facilitated the interpretation of the results described.

In line with the results described for the FPT and DDT in the left ear, another study can be cited, which carried out assessment and intervention with subjects with hearing loss. The training applied also consisted of eight sessions, but used different verbal and non-verbal sound activities. This study also obtained improvement in the CAP tests, in which the FPT and DPT are included[21].

In the present research, although no statistically significant difference was observed in all pre- and post-intervention tests, it was possible to qualitatively and without statistical inference observe a tendency towards improvement in the results for most of the tests applied after auditory training (Figure 1), suggesting possible modifications in the auditory system generated by the intervention[23,25-27]. Despite this, the absence of a statistically significant difference does not allow us to affirm that the MAT offered remotely is effective in improving these skills. It is believed that these results may be related to the small sample size and the fact that this type of training only allows exercises with non-verbal stimuli. Another issue that should be considered is the lack of electrophysiological tests to check for possible changes in auditory pathway functionality in these individuals, since patients with CAPD also presented functional changes in the auditory pathways[28], and these measures would be interesting to check for changes.

Considering the same analysis (normal and altered), there was a difference for the DDT of the left ear and the FPT, reinforcing once again the reliability of the results found in the quantitative analysis (Table 2).

Recent evidence shows that the practice of teleaudiology in hearing intervention services has demonstrated equivalent and, in some cases, superior results to in-person care. However, this new technology still presents limitations due to challenges such as the lack of adequate technological infrastructure, inequality in internet access, lack of digital literacy, and patients' concerns regarding data confidentiality[29].

Although the results are promising, it must be considered that a control group was not used for comparison in this study due to the difficulty of recruiting and retaining individuals in the research. Therefore, they should be interpreted with caution, as the possibility that individuals presented better responses in the reassessment simply because they were undergoing a procedure after the training, which may have positively influenced their attention during the reassessment.

Regarding user satisfaction with the service provided and other related aspects, positive points were highlighted in the quality of service and satisfaction with the care received. These results are consistent with current literature, in which a Brazilian study evaluated user satisfaction in a public reference program for cochlear implants, with hybrid care, including guidance on audiological aspects, auditory training, parent coaching, and specialized teleconsultations, finding that most patients evaluated the care positively and would use the service again. Furthermore, the study concluded that teleaudiology guarantees faster access for users, significant cost-benefit, as well as personalization and diversification of care[11]. Another study conducted with hearing aid users also reported that most users felt satisfied or very satisfied with the use of the prostheses and also stated that they liked the remote care and the ease of use of the system[30].

These satisfaction results and the fact that most individuals in this study reported that the service offered resolved their complaints reinforce the importance of telerehabilitation for auditory training, especially for maintaining the consistency of weekly appointments. These findings may be useful for services within the Brazilian Unified Health System (SUS) and in contexts of low accessibility for users, enabling service provision across various regions of the country. However, it should be considered that the questionnaire was developed by the researchers themselves, without validation.

Study limitations

One of the study's limitations was the absence of a control group for statistical comparisons. Although comparing pre- and post-intervention results is useful for verifying intra-subject changes and assessing the feasibility of the intervention, caution must be exercised in interpreting the results due to the lack of robust evidence and the difficulty in ruling out improvements resulting from external factors, such as the placebo effect, learning, or time. The lack of randomization and the small sample size limited the generalizability of the results, as it is believed that a larger number of patients could generate significant results in all the behavioral tests applied.

The specific limitation regarding online care was the unstable internet connection at some patients' homes. Given this, it was necessary to reschedule some sessions, without impacting the research results.

CONCLUSION

The use of teleaudiology through synchronous remote care and with the Musical Auditory Training platform indicates a positive effect on the rehabilitation of Central Auditory Processing Disorder, mainly for auditory figure-ground skills for verbal sounds and temporal ordering for frequency.

Participants demonstrated satisfaction with the quality of service, improvements in symptoms, and considered the online training format accessible, positively reinforcing the practice of teleaudiology.

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