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Original article
Artigo Original

Figure-background in dichotic task and their relation to skills untrained

Figura-fundo em tarefa dicótica e sua relação com habilidades não treinadas

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Keywords

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ABSTRACT

Purposes: To evaluate the effectiveness of auditory training in dichotic task and to compare the responses of trained skills with the responses of untrained skills, after 4–8 weeks. **Methods:** Nineteen subjects, aged 12–15 years, underwent an auditory training based on dichotic interaural intensity difference (DIID), organized in eight sessions, each lasting 50 min. The assessment of auditory processing was conducted in three stages: before the intervention, after the intervention, and in the middle and at the end of the training. Data from this evaluation were analyzed as per group of disorder, according to the changes in the auditory processes evaluated: selective attention and temporal processing. Each of them was named selective attention group (SAG) and temporal processing group (TPG), and, for both the processes, selective attention and temporal processing group (SATPG). **Results:** The training improved both the trained and untrained closing skill, normalizing all individuals. Untrained solving and temporal ordering skills did not reach normality for SATPG and TPG. **Conclusions:** Individuals reached normality for the trained figure-ground skill and for the untrained closing skill. The untrained solving and temporal ordering skills improved in some individuals but failed to reach normality.

Descritores

Fonoaudiologia
Audição
Transtornos da Audição
Percepção Auditiva
Transtornos da Percepção Auditiva

RESUMO

Objetivos: Verificar a eficácia do treinamento auditivo em tarefa dicótica e comparar as respostas da habilidade treinada com as repostas das habilidades não treinadas, após quatro e oito semanas. **Métodos:** 19 indivíduos, de 12 a 15 anos foram submetidos a um treinamento auditivo baseado no DIID e organizados em 8 sessões, com duração de 50 minutos por sessão. Realizaram a avaliação do processamento auditivo em três momentos: pré-intervenção, pós-intervenção na metade e no final do treinamento. Os dados desta avaliação foram analisados por grupo de distúrbio de acordo com as alterações nos processos auditivos avaliados: atenção seletiva e processamento temporal. Em cada um deles, denominado Grupo atenção seletiva (GAS) e Grupo processamento temporal (GPT), e em ambos os processos: Grupo atenção seletiva e processamento temporal (GASPT). **Resultados:** O treinamento melhorou a habilidade treinada e a não treinada de fechamento, normalizando todos os indivíduos. As habilidades não treinadas de resolução e ordenação temporal não atingiram a normalidade no GASPT e GPT. **Conclusão:** Os indivíduos alcançaram a normalidade para a habilidade treinada de figura-fundo e paraa não treinada de fechamento. Já as habilidades não treinadas de resolução e ordenação temporal melhoraram em alguns indivíduos, porém não atingiram a normalidade.

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INTRODUCTION

Individuals with auditory processing disorder may present manifestations such as psycholinguistic problems; reading and writing problems; poor school performance; social behavior disorders; hearing-specific clinical problems regarding the location of the sound source and discrimination of sounds; identification; and memory[1].

In seeking to reduce the impact in communication and school of an auditory processing disorder, it is necessary, in addition to auditory training, to improve how the brain deals with the acoustic signal and the use of strategies that involve language, cognition, and metacognition, which promote plasticity and cortical reorganization[2-4].

Neuroplasticity is the ability of the nervous system to adapt to different stimuli. The ability for anatomical and functional changes in the system responsible for auditory information is called auditory plasticity[5]. The plasticity is observed by behavioral and electrophysiological changes[6,7]. Many studies have shown these changes after the auditory training was administered[7,8].

Studies show that formal hearing training increases the possibility of an audiological intervention in children with auditory processing disorder[9]. It is shown in the literature that individuals have also benefited from the training in tasks that work with the temporal auditory processing and tasks involving dichotic hearing[8].

The dichotic interaural intensity difference (DIID) is an auditory training proposed by Musiek[11], in which the stimuli are presented initially in a less-intense noise level in the better ear and at a fixed, more intense level in the worst ear. The objective of this training is to provide challenges of speech recognition, via the worst ear, in dichotic tasks. The training is done with separation and binaural integration activities[11,12]. The literature shows that, after training the worst ear, both ears reach a good performance in dichotic tests[11]. Some studies with this training observed improvement in speech and language skills in children with learning disabilities[12].

Thus, this study sought to assess whether the improvement by this particular type of training can be generalized to other skills for the auditory training program to be effective, in order to contribute to a better quality of life for people with auditory processing disorders, with changes in the physiological mechanisms of selective attention and/or temporal processing.

This study aimed to verify the effectiveness of the DIID approach by comparing the responses for the trained figure-ground task with the responses for the untrained temporal closing, ordering, and resolution tasks. Therefore, it was necessary to establish them at three auditory-verbal rehabilitation moments: pre-, during and postintervention, in the groups with changes in the physiological mechanisms of selective attention and/or temporal processing.

METHODS

The study was carried out in the clinic of the Clinic of the Hearing disorders, auditory processing evaluation service, Neurology sector. It was approved by the Ethics and Research Committee of the Speech-Language Pathology and Audiology Department of Universidade Federal de São Paulo (CAAE: 15220013.0.0000.5505) under protocol no. 304.548, and received funding from Conselho Nacional de Desenvolvimento Científico e Tecnológico (CNPq, 133260/2013-5). The volunteers and their parents signed a free and informed consent.

We selected 19 individuals, all of them volunteers aged 12–15 years, from the patients treated at the neuro-audiology clinic of the Speech-Language Pathology and Audiology Department. The level of education ranged from the sixth grade of elementary school to the first year of high school.

The data were analyzed by distributing the individuals in groups according to the changes in physiological mechanisms, selective attention, temporal processing, or both. This group division was carried out in order to verify the effectiveness of the auditory training with dichotic listening in different population with auditory processing disorders. Thus, the individuals were divided in groups as follows:

- SATPG (selective attention and temporal processing group): six individuals who showed changes in the physiological mechanisms of selective attention and temporal processing in their auditory processing evaluation were verified by tests such as Speech in White Noise (SWN), Dichotic Staggered Spondaic Word (DSSW) test, Random Gap Detection Test (RGDT), and Duration Pattern Test (DPT). It is noteworthy that the individuals in this sample showed changes in at least three of the four above-mentioned tests.
- SAG (selective attention group): six individuals who showed changes in the physiological mechanism of selective attention in their auditory processing evaluation were verified with SWN and DSSW tests. It is important to highlight that all individuals in this sample showed a change in both the tests described. The physiological mechanism of temporal processing was found to be normal in this sample, verified through RGDT and DPT.
- TPG (temporal processing group): seven individuals who showed changes in the physiological mechanism of temporal processing in their auditory processing evaluation were verified by RGDT and DPT. Thus, we must emphasize that the individuals in this sample showed changes in at least one of the tests. The physiological mechanism of selective attention was found to be normal in this sample, verified by the SWN and DSSW tests.

Inclusion criteria

Adolescents aged 12–15 years, who showed auditory processing disorders and asymmetry in the percentages of correct responses between both ears in the DSSW test; this asymmetry varied with a minimum value of 2.5% and a maximum of 17.5% between the ears (minimum difference of one and maximum difference of seven items) and was observed in all subjects; it was through this asymmetry that the ear with a lower percentage of correct responses was chosen to be trained.

Exclusion criteria

Individuals with auditory processing disorders, already performed auditory training, changes in speech, hearing loss, and evidence of cognitive impairment were excluded.

Assessment of the selective attention and temporal processing auditory processes through behavioral tests

The materials used to perform the auditory processing evaluation were the CDs that come with the book *Processamento Auditivo Central: Manual de Avaliação* (Central Auditory Processing: Assessment Manual)[13], RGDT (Random Gap Detection) by Auditec[14], and Duration Pattern proposed by Musiek[15]. Routine behavioral tests were performed for the evaluation of auditory processing in three stages: preauditory training, named moment T0, in the middle of auditory training, (i.e., after four sessions), named T1, and after eight training sessions, the postauditory training moment, called T2. We chose to reassess the individuals in the middle and at the end of the auditory training, in order to observe if the auditory training was being effective. The tests were presented briefly regarding the hearing abilities evaluated:

- Closing skill: SWN: The test was applied in a monotic fashion. The normality criterion was a percentage of correct responses ≥ 70% and a difference between the SRI with recording and the SWN < 20%[13].
- Figure-ground auditory skill for verbal sounds: The test was applied in a dichotic fashion. In DSSW test, the normality criteria for the sample was 1%≥90% in the right and may have at the most one inversion[13].
- Temporal resolution skill: The test was applied in the binaural form. In RGDT, The normality criteria for this sample was ≤10 ms[14].
- Temporal ordering skill of brief and successive sounds: The test was applied in the binaural form. In DPT – Musiek:, the normality criteria for this sample was ≥83% of accuracy[15].

Therapeutic intervention – Auditory training

The acoustically controlled auditory training proposed in this study was adapted from DIID training, organized into eight sessions carried out once or twice a week. Each session lasted 50 min[16]. The materials used to apply the training were the CDs that come with the book *Processamento Auditivo Central: Manual de Avaliação* (Central Auditory Processing: Assessment Manual)[13] and the list of sentences in Portuguese[17]. Dichotic tests were selected because of the approach chosen. The difficulty of each task in the cabin training was set for each test and for each session aiming to keep the success versus error rate at approximately 70%/30%[8]. Training procedures were scheduled so that the same type of task was rarely used in two sessions in a row. The schedule of auditory training sessions and the activities proposed in each of them were described to facilitate the understanding of what was carried out in chronological order since the first session (Chart 1).

Behavioral reassessment

In the reassessment sessions (moments T1 and T2), subjects underwent the same procedures described in assessment of auditory processing.

Statistical method

The analysis was performed by a trained professional, by means of nonparametric tests and descriptive statistics. The tests used were the Mann-Whitney test, Friedman test, and Wilcoxon test. A 0.12 significance level (12%) was adopted. The statistical error used in this study is higher than what is generally used (5%) because of the small sample (< 30 individuals). It is noteworthy that the confidence intervals were built with 95% statistical confidence.

RESULTS

First, the population was divided into three groups according to the physiological mechanism changed: SATPG, six individuals with changes in selective attention and temporal processing; SAG, six individuals with changes exclusively in selective attention; TPG, seven individuals with changes exclusively in temporal processing. Half the number of the subjects in each group received one session per week, and the other half the number of subjects received two sessions per week.

Mean ages (years) were similar between the groups, with no statistical difference. The average was 13.00, 13.83, and 13.57 in SATPG, SAG, and TPG, respectively.

There was a statistical difference in the SWN test in all groups (Table 1) when comparing all moments among themselves, T0, T1, and T2, both the right ear and the left ear, except for the comparison between the moments T1 and T2 of the TPG in the left ear, which tended to significance.

Performance in the SWN test improved after training in both ears in the three groups.

There was an improvement in performance in speech recognition of low predictability words, SSW test after the intervention with statistical significance in all groups (Table 2), both on the right ear and on the left ear.

There were statistically significant differences (Table 3) in RGDT responses in all groups when all the moments were compared among each other, T0, T1, and T2; therefore, all patients revealed a significant improvement in this test. The biggest change in threshold and temporal acuity occurred after eight training sessions.

There were statistically significant differences (Table 4) in the TDP humming and naming in all groups when all moments were compared among each other, T0, T1, and T2. All the patients revealed a significant improvement in these tests. The biggest change in performance occurred after eight sessions of TAAC.

The study of trained auditory skills (figure-ground) was shown, and those not involved in the TAAC proposed in this study were closing, temporal resolution, and temporal ordering.

Auditory skills were classified as normal or altered, and the statistical analysis was performed with testing for equality of proportions, complemented by the Wilcoxon test when necessary (Chart 2).

In the closing skill (SWN), all individuals in SATPG and SAG revealed changes in this skill at moment T0, and at the end of the intervention, at moment T2, all reached normality. It is noteworthy that, at time T1, the majority of individuals of both groups presented normality for this skill.

In the figure-ground skill (DSSW test), all individuals in SATPG and SAG showed changes in this skill at moment

Chart 1. Description of the auditory training sessions

Sessions	Skill	Test	Fixed noise level for the worse ear	Relation	Binaural separation task (point/speak the stimuli for the worst ear)	Behavioral test	Integration binaural task (speak the stimuli for both ears)
1st session	Figure-ground	Dichotic task	dB	+20 +10 0 -10 -20	Familiar words Listen to and point one	DDT	
2nd session	Figure-ground	Dichotic task	dB	+20 +10 0 -10 -20 -30 -40	Non-verbal stimulus Listen to and point one	NVDT	
3rd session	Figure-ground	Dichotic task	dB	+20 +10 0 -10 -20 -30 -40	Sentences Listen to and point one	Test PSI/SSI CCM	
4th session	Figure-ground	Dichotic task	dB	+20 +10 0 -10 -20	Sentences Listen to and speak one	IRS	
5th session	Figure-ground	Dichotic task	dB	+20 +10 0 -10 -20	Syllables Listen to and point one	CVDT	
6th session	Figure-ground	Dichotic task	dB	+20 +10 0 -10 -20	Syllables Listen to and speak one	CVDT	
7th session	Figure-ground	Dichotic task	dB	0		DDT	Familiar Words Listen and repeat the stimuli of both ears
8th session	Figure-ground	Dichotic task	dB	0		NVDT CVDT	Syllables Listen and repeat the stimuli of both ears

Caption: PSI/SSI = dichotic hearing test with sentences; SRTN = sentence recognition threshold in noise; DDT = dichotic digits test; NVDT = non-verbal dichotic test; CVDT = consonant-vowel dichotic test; CCM = contralateral competitive message.

T0, and at the end of the intervention, at moment T2, all reached normality.

In the temporal resolution skill (RGDT), all individuals in SATPG and most in TPG showed changes in this skill at moment T0, and at the end of the intervention, at moment T2, more than half of these two groups reached normality.

In the temporal ordering skill (humming DPT), all individuals in SATPG and TPG showed changes in this skill at moment

Table 1. Descriptive statistics for correct responses in the speech in White noise test for right and left ears and p-value calculated for comparison using the Friedman test and comparison between the moments of the intervention using the Wilcoxon test

Test	Groups	T0	T1	T2	p-value	T0XT1 (p-value)	T0X T2 (p-value)	T1XT2 (p-value)
SWN RE	SATPG	69.33%	78.00%	85.33%	0.002*	0.020*	0.026*	0.026*
SWN LE	SATPG	66.00%	76.67%	84.00%	0.003*	0.026*	0.028*	0.039*
SWN RE	SAG	72.00%	82.67%	88.00%	0.002*	0.027*	0.027*	0.020*
SWN LE	SAG	72.67%	82.00%	88.67%	0.002*	0.026*	0.026*	0.026*
SWN RE	TPG	81.71%	83.43%	85.15%	0.030*	0.083*	0.063*	0.083*
SWN LE	TPG	81.71%	83.43%	84.57%	0.037*	0.083*	0.059*	0.157#

Friedman test and Wilcoxon test; *statistically significant; #tendency to significance.

Caption: SWN = speech in White noise; RE = right ear; LE = left ear; SATPG = selective attention and temporal processing group; SAG = selective attention group; TPG = temporal processing group; T0 = pre-intervention moment; T1 = post-intervention moment for 4 sessions; T2 = post-intervention moment for 8 sessions.

Table 2. Descriptive statistics for correct responses in the dichotic staggered spondaic word test for right and left ears and p-value calculated for comparison using the Friedman test and comparison between the moments of the intervention using the Wilcoxon test

Test	Groups	T0	T1	T2	p-value	T0XT1 (p-value)	T0X T2 (p-value)	T1XT2 (p-value)
SSW OD	SATPG	77.08%	86.67%	92.92%	0.003*	0.042*	0.026*	0.020*
SSW OE	SATPG	80.83%	87.92%	94.17%	0.002*	0.027*	0.028*	0.027*
SSW OD	SAG	80.42%	87.92%	94.17%	0.008*	0.056*	0.028*	0.043*
SSW OE	SAG	76.25%	89.17%	94.17%	0.006*	0.046*	0.027*	0.026*
SSW OD	TPG	92.50%	95.36%	97.86%	0.005*	0.039*	0.024*	0.066*
SSW OE	TPG	92.86%	95.36%	97.50%	0.002*	0.020*	0.016*	0.034*

Friedman test and Wilcoxon test; *statistically significant.

Caption: SSW = dichotic staggered spondaic word test; RE = right ear; LE = left ear; SATPG = selective attention and temporal processing group; SAG = selective attention group; TPG = temporal processing group; T0 = pre-intervention moment; T1 = post-intervention moment for 4 sessions; T2 = post-intervention moment for 8 sessions.

Table 3. Descriptive statistics for the average of random gap detection test and p-value calculated for the comparison using the Friedman test and comparison between the moments of the intervention using the Wilcoxon test

Test	Groups	T0	T1	T2	p-value	T0XT1 (p-value)	T0X T2 (p-value)	T1XT2 (p-value)
RGDT	SATPG	41.85ms	19.42ms	9.70ms	0.002*	0.028*	0.028*	0.028*
RGDT	SAG	8.32ms	7.63ms	6.02ms	0.004*	0.066*	0.027*	0.027*
RGDT	TPG	35.33ms	21.41ms	10.43ms	0.001*	0.018*	0.018*	0.018*

Friedman test and Wilcoxon test; *statistically significant.

Caption: RGDT = random gap detection test; SATPG = selective attention and temporal processing group; SAG = selective attention group; TPG = temporal processing group; T0 = pre-intervention moment; T1 = post-intervention moment for 4 sessions; T2 = post-intervention moment for 8 sessions.

Table 4. Descriptive statistics for the percentage of responses in the humming duration pattern test and naming duration pattern test and p-value calculated for comparison using the Friedman test and comparison between the moments of the intervention using the Wilcoxon test

Test	Groups	T0	T1	T2	p-value	T0XT1 (p-value)	T0X T2 (p-value)	T1XT2 (p-value)
TPD H	SATPG	52.73%	62.18%	72.18%	0.002*	0.027*	0.028*	0.026*
TPD N	SATPG	46.65%	54.95%	62.20%	0.003*	0.043*	0.027*	0.027*
TPD H	SAG	88.85%	92.75%	96.62%	0.003*	0.026*	0.026*	0.041*
TPD N	SAG	84.97%	89.40%	92.20%	0.004*	0.023*	0.026*	0.066*
TPD H	TPG	69.50%	76.16%	80.90%	0.002*	0.042*	0.018*	0.042*
TPD N	TPG	61.40%	69.01%	74.26%	0.002*	0.043*	0.018*	0.043*

Friedman test and Wilcoxon test; *statistically significant.

Caption: DPT = duration pattern test; H= humming; N= naming; SATPG = selective attention and temporal processing group; SAG = selective attention group; TPG = temporal processing group; T0 = pre-intervention moment; T1 = post-intervention moment for 4 sessions; T2 = post-intervention moment for 8 sessions.

T0, and at the end of the intervention, at moment T2, half the number of the individuals in SATPG and about half of those in TPG reached normality.

DISCUSSION

The results obtained regarding the evolution of figure-ground, closing and temporal ordering, and resolution auditory skills, after an intervention that prioritized the figure-ground skill in a dichotic hearing task with verbal and nonverbal sounds, were analyzed critically comparing them, where possible, with other studies.

As for the selective attention function measured by the performance in speech perception in noise, a comparative analysis was performed at different times of auditory training, before (T0), during (T1), and after (T2), and an improvement was observed as the number of sessions increased, with a statistical significance in all groups: SATPG, SAG, and TPG.

These results came from those found in the literature, in the works of Zalcman and Schochat[18] and Alonso and Schochat[19], who applied auditory training in students aged 8–16 years with processing disorders and used the SWN test to assess the closing skill pre- and posttraining. Auditory training improved the closing skill in this study and other studies. It is noteworthy that this study did not work with the closing skill in training sessions, unlike other studies in the literature, as these have focused on skills that showed changes. Therefore, auditory training involving dichotic tasks is effective in the untrained closing skill for this study.

As for the selective attention function, measured by performance in the SSW, a comparative analysis was performed at different moments of auditory training, before (T0), during (T1), and after (T2), and an improvement was observed as the number of sessions increased, with statistical significance in all groups: SATPG, SAG, and TPG.

The results of this analysis showed an increase in the figure-ground skill after training, and those found in the literature, in the works of Zalcman and Schochat[18], Alonso and Schochat[19], Cruz, Andrade and Gil[20] and Filippini, Brito, Lobo and Schochat[21], who applied the auditory training in children and adults with processing disorders and used SSW to assess the figure-ground skill pre- and posttraining. Auditory training improved the figure-ground skill in this study and in other studies.

In this study, all patients improved their performance in the DSSW test in both ears, which was found in the study involving auditory training with dichotic individuals, prioritizing the worst ear, held by Musiek[11]; in this study, it was found that, although training was applied to the ear that had the worst performance (in the binaural separation step), there was also an improvement in the untrained ear, which can be verified by the dichotic listening tests.

As for the temporal processing function measured by performance in the RGDT, comparative analysis was performed at different moments of auditory training, before (T0), during (T1), and after (T2), and an improvement was observed as the number of sessions increased, statistically significant in all groups: SATPG, SAG, and TPG.

No data were found in the literature that assessed the temporal resolution ability under the intervention of an auditory training in students with processing disorders, but in the study by Marangoni and Gil[22] with adults who underwent formal auditory training after cranial trauma, they were assessed and reassessed with RGDT and showed an improvement. In a case study by Hurley and Hurley[23] with a patient with Landau-Kleffner syndrome, an improved performance in RGDT was shown. Although the population of these aforementioned studies differs, they corroborate the current study because there was an evolution in the hearing ability after temporal resolution training.

As for the temporal processing function as measured by performance on DPT, comparative analysis was performed at different moments of the auditory training, before (T0), during (T1), and after (T2), and an improvement was observed as the number of sessions increased, statistically significant in all groups: SATPG, SAG, and TPG.

Chart 2. Occurrence of auditory skills classified as normal and altered

	SATPG	SAG	TPG
% of normality for the closing skill (moment T0)	0%	0%	100%
% of normality for the closing skill (moment T1)	66.7%	83.3%	100%
% of normality for the closing skill (moment T2)	100%	100%	100%
% of normality for the figure-ground skill (moment T0)	0%	0%	100%
% of normality for the figure-ground skill (moment T1)	16.7%	33.3%	100%
% of normality for the figure-ground skill (moment T2)	100%	100%	100%
% of normality for the temporal resolution skill (moment T0)	0%	100%	14.3%
% of normality for the temporal resolution skill (moment T1)	33.3%	100%	28.6%
% of normality for the temporal resolution skill (moment T2)	66.7%	100%	71.4%
% of normality for the temporal ordering skill (moment T0) - Humming	0%	100%	0%
% of normality for the temporal ordering skill (moment T1) - Humming	16.7%	100%	42.9%
% of normality for the temporal ordering skill (moment T2) - Humming	50%	100%	57.1%
% of normality for the temporal ordering skill (moment T0) - Naming	0%	100%	0%
% of normality for the temporal ordering skill (moment T1) - Naming	16.7%	100%	14.3%
% of normality for the temporal ordering skill (moment T2) - Naming	16.7%	100%	57.1%

Caption: SATPG = selective attention and temporal processing group; SAG = selective attention group; TPG = temporal processing group; T0 = pre-intervention moment; T1 = post-intervention moment for 4 sessions; T2 = post-intervention moment for 8 sessions.

These results showed an evolution in DPT after training, as noted in the literature, in the study by Cruz, Andrade and Gil[20]. Auditory training improved the temporal ordering ability in this study and in the other study. Note that this study did not work with the temporal ordering ability in training sessions, unlike the study in the literature, for the latter focused on the skills that showed changes.

The data from this study corroborate the results found in the literature, in studies by Zalcman and Schochat[18]; Alonso and Schochat[19]; Cruz, Andrade and Gil[20]; and Filippini, Brito, Lobo, and Schochat[21], which verified the effect of auditory training in children/adults with auditory processing disorders. In this research, we found statistically significant differences when comparing the auditory processing assessment performed before, during, and after the auditory training with an improvement in all tests. This improvement is related to the capacity of the central nervous system to cause changes owing to environmental stimuli, and this capacity is defined as neuronal plasticity[5].

This particular type of training showed improvement in the trained figure-ground skill and in the untrained closing and temporal resolution and ordering skills in this study, as noted in the work by Musiek and Schochat[24]; however, in the comparative study, the auditory training proposed worked with the worst ear in dichotic tasks, based on DIID, and worked with other skills such as location, temporal resolution, and ordering in students.

In this study, we also considered the classification of listening skills regarding normality.

In the closing skill, assessed by the SWN test, 12 volunteers who showed changes in this skill (volunteers from SATPG and SAG) improved and normalized this skill, corresponding to a 100% improvement. The other participants who were allocated in the TPG (seven individuals) already showed baseline normality for this skill. After the first four sessions, 75% of individuals in these two groups showed normality for this skill.

There was an improvement and normalization in all individuals who showed changes in the closing skill. Speech recognition in noise is a task that requires the use of selective attention, because the listener needs to focus attention on the main message, while trying to ignore the irrelevant information. The hypothesis is that there was a generalization of this skill, because by training the dichotic hearing, the listener could focus more attention on the main message, managing to ignore the competitive noise and performing the auditory closing.

In the figure-ground skill, evaluated by DSSW test, the 12 volunteers (100%) allocated in SATPG and SAG improved and normalized this skill after eight sessions.

The literature[3,18] states that three kinds of plasticity can occur in the auditory system: developmental plasticity and compensatory plasticity, which results from injury occurred in the auditory system, and the plasticity associated with learning. The plasticity occurred in this study regarding the improvement of the figure-ground skill was related to learning, because the volunteers underwent a training program with dichotic stimuli.

This improvement in the untrained closing skill and the trained figure-ground skill can be related to the idea defended by Musiek and Berge[25], in which the evolution of auditory skills probably arose as a response to environmental influences previously determined and modified in the desired manner, which led to a neural change. Therefore, auditory training was able to stimulate the neural structures related to the performance of auditory closing and figure-ground skills, benefiting individuals who showed changes in these skills.

In the temporal resolution skill, assessed by RGDT, more than half the number of the individuals allocated in the SATPG (100% with changes in temporal resolution) and TPG (85.71% with changes in resolution) improved and normalized this skill after eight sessions.

In the temporal ordering skill, measured by the humming DPT, about half the number of the 13 individuals allocated in SATPG and TPG improved and normalized this skill after eight sessions; in the naming DPT, 38.46% of the 13 members of SATPG and TPG improved and normalized this skill after eight sessions. It is worth noting that, in SATPG, the six members showed changes in temporal ordering/naming and humming, and, in TPG, seven participants showed changes in ordering/naming and humming.

The untrained temporal resolution and ordering skills improved in some individuals but did not reach the expected normality for those who showed changes in the physiological mechanism of temporal processing. There was no generalization of temporal resolution and ordering skills with the auditory training with dichotic hearing. Temporal processing is related to speech perception, and difficulty in perceiving rapid changes in the acoustic signal can influence the perception of sound and, later on, speech recognition[26]. One of the most basic and important functions of the nervous system is related to the temporal processing, which is the task of sequencing stimuli[27]. Thus, these temporal skills cannot be generalized by only training dichotic stimuli, it is necessary that the training of an individual with abnormal temporal processing involve all hearing abilities that show changes.

According to the results, it can be noted that the auditory training program may not be fully effective in all patients, because not all individuals in the groups who showed changes in temporal processing (SAG and TPG) met the normality criteria expected for their age group. This demonstrates that only sessions with dichotic hearing were not enough to suit all the needs of some individuals who have changes in the physiological mechanism of temporal processing.

In the specialized literature consulted until the end of the search for scientific articles, no similar studies were found to compare the results of this study.

This study has limitations, because the closing, temporal resolution, and temporal ordering skills were not trained, and part of the volunteers who showed changes in temporal processing did not reach the expected standard of normality. It is shown in the literature that the auditory training promotes plasticity[7,8]; however, it is not only the auditory training alone, or only focused on one auditory skill, that will bring the greatest benefits to the individual. There is a need for a general approach to auditory training, aiming to rehabilitate all auditory skills.

Another limitation was the completion of homework assignments. At the baseline, tasks were developed for volunteers to perform at home, but most parents and guardians claimed that they worked all day and could not control if minors would be performing such tasks; so, these tasks were dropped from the study.

Regarding the performance of the total sample highlighted in each of the eight sessions, we predominantly emphasized the total sample and did not focus on the types of groups. Regarding the performance in auditory training sessions, the groups presented an average of correct responses that was higher than expected. In the first four sessions, which worked with stimuli with numbers, onomatopoeia, and phrases (binaural separation), all groups showed averages of correct responses above 90%. The fifth and sixth sessions, which worked with syllables stimuli, were more challenging, and groups showed averages above 69%. In the seventh session, with numbers stimuli, at the binaural integration stage, the groups showed averages above 80%; in the first stage of the eighth session, with onomatopoeia stimuli, at the binaural integration stage, the groups showed averages above 97%; in the second stage of the eighth session, with syllabic stimuli, at the binaural integration stage, the groups showed averages above 48% in the first practice and 65% in the second practice.

Some tasks of the auditory training in this study were not very challenging, seeing as the success rate was higher than 70%, especially when linguistic stimuli with meaning were used. Training showed that syllables were more challenging than the stimuli with numbers, onomatopoeic sounds, and phrases.

Murphy and Schochat[10] recommend maintaining the success rate versus approximate error of 70%/30% that was verified in training with dichotic hearing listening to syllables. The other types of training revealed success rates higher than 70%.

There was great adherence by individuals and their families, who always attended training sessions punctually, accompanied by their guardians and at the end of each session, they shared their views with the therapist. Their guardians always reported improvements concerning the attentional aspects during the training.

Schochat et al.[24] state that the auditory training must be intensive, have compliance from the patients and the family that supports them, and have challenging activities for the central nervous system and be helpful, in order to maintain the individual's motivation, avoiding frustration.

Thus, we find that the auditory training proposed in this study was intensive, revealed adherence by the volunteers, and showed challenging activities for the central nervous system. Probably, the least challenging activities guaranteed the individual's motivation, as they reduced the frustration of failure.

CONCLUSION

Auditory training, with emphasis on the figure-ground skill in dichotic hearing, has improved and normalized the trained skill in all individuals with this disability in the SATPG and SAG and improved and normalized the untrained closing ability on SATPG and SAG.

The untrained temporal resolution and ordering skills improved in some individuals with this inadequacy in SATPG and TPG but did not reach the expected normality levels.

APC was the lead researcher, study design, development of the schedule, literature review, collection and analysis of data, drafting of the article, article submission and procedures; LDP was the supervisor, study design, development of the schedule, revision of the article, approval of the final version.

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