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Comparison between isolated phonological therapy and when associated to computerized auditory training in the rehabilitation of phonological disorders in children

Comparação entre a terapia fonológica isolada ou associada ao treinamento auditivo computadorizado na reabilitação dos transtornos fonológicos em crianças

Comparación entre la terapia fonológica aislada o asociada al entrenamiento auditivo computarizado en la rehabilitación de los trastornos fonológicos en niños

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Abstract

Introduction: The auditory training is an intervention method used to improve the performance of auditory skills, aiming to enhance the processing of sound information. **Objective:** To assess the effectiveness of central auditory processing stimulation in the rehabilitation of phonological disorders. **Method:** A case study of six children aged between 6:00 and 7:11 diagnosed with phonological disorder.

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Authors' contributions:
PTM: carried out the elaboration and writing of the project, data collection and writing of the paper.
LMD: made the suggested modifications and placed the paper in the norms of the journal.
SAB: co-guided the work in all its stages and reviewed the paper.
CLM: guided the performance of the work in all its stages and carried out the review of the paper.

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All children underwent speech-language assessment, with specific assessment of phonology through the Child's Phonological Assessment (Yavas, Hernandorena e Lamprecht, 2002) and temporal processing skills through the temporal ordering and resolution tests, before and after therapy. All subjects underwent 25 therapy sessions, with three subjects undergoing only phonological therapy (study group 1 - SG1), and the other three went through phonological therapy associated with computerized auditory training (study group 2 - SG2), using the software Escuta Ativa. **Results:** There was no statistically significant difference when comparing the results of performance in tasks concerning the perception of the phonological system and the temporal processing in the same tests (set of tasks of listening skills) applied before and after therapy of SG1 with SG2. However, there was an improvement in the performance of temporal processing tests for SG2. **Conclusion:** Phonological therapy combined with computerized auditory training in children with phonological disorders did not show a statistically different difference, however it did influence the increase in the performance of temporal processing tests in these children when compared to the isolated use of phonological therapy.

Keywords: Speech perception; Auditory perception; Speech-Language Pathology; Rehabilitation of Speech and Language Disorders

Resumo

Introdução: O treinamento auditivo é um método de intervenção utilizado para aprimorar o desempenho das habilidades auditivas alteradas, de modo que, pode promover melhora no processamento da informação sonora. **Objetivo:** Verificar a eficácia da estimulação do processamento auditivo central na reabilitação dos transtornos fonológicos. **Método:** Foi realizado um estudo de caso de seis crianças com idades entre 6:00 e 7:11 de idade, com diagnóstico de transtorno fonológico. Todas as crianças passaram por avaliação fonoaudiológica, com avaliação específica da fonologia por meio da Avaliação Fonológica da Criança (Yavas, Hernandorena e Lamprecht, 2002) e pela avaliação das habilidades de processamento temporal por meio dos testes de ordenação e resolução temporal, pré e pós terapia. Todos os sujeitos passaram por 25 sessões de terapia, sendo que três sujeitos foram submetidos à terapia puramente fonológica (grupo de estudo 1 - GE1), e as outras três crianças receberam terapia fonológica associada ao treinamento auditivo computadorizado (grupo de estudo 2 - GE2), com o *software* Escuta Ativa. **Resultados:** Não houve diferença estatisticamente significativa quando comparados os resultados do desempenho em tarefas concernentes a percepção do sistema fonológico e do processamento temporal nos mesmos testes (conjunto de tarefas com habilidades auditivas) aplicados pré e pós terapia do GE1 com o GE2. Contudo, houve melhora no desempenho dos testes de processamento temporal em GE2. **Conclusão:** A terapia fonológica combinada ao treinamento auditivo computadorizado em crianças com transtorno fonológico não evidenciou diferença estatisticamente diferente, porém demonstrou influenciar no aumento do desempenho dos testes de processamento temporal destas crianças quando comparado ao uso isolado da terapia fonológica.

Palavras-chave: Percepção da fala; Percepção auditiva; Patologia da Fala; Reabilitação dos Transtornos da Fala e da Linguagem.

Resumen

Introducción: el entrenamiento auditivo es un método de intervención utilizado para perfeccionar el desempeño de las habilidades auditivas alteradas, de modo que, puede promover mejora en el procesamiento de la información sonora. **Objetivo:** verificar la eficacia de la estimulación del procesamiento auditivo central en la rehabilitación de los trastornos fonológicos. **Método:** Fue realizado un estudio de casos de seis niños con edades de 6:00 a 7:11 años, con diagnóstico de trastorno fonológico. Todos los niños pasaron por evaluación fonoaudiológica, con evaluación específica de fonología por medio de la Evaluación Fonológica del Niño (Yavas, Hernandorena e Lamprecht, 2002) y por la evaluación de las habilidades de procesamiento temporal por medio de los test de coordinación y resolución temporal, pre y post terapia. Todos los sujetos pasaron por 25 sesiones de terapia, siendo que tres sujetos fueron sometidos a la terapia puramente fonológica (grupo de estudio 1 - GE1),y los otros tres niños recibieron

terapia fonológica asociada al entrenamiento auditivo computarizado (grupo de estudio 2 - GE2), con el *software* Escuta Ativa. **Resultados:** No hubo diferencia estadísticamente significativa cuando comparados los resultados del desempeño en tareas concernientes a la percepción del sistema fonológico y del procesamiento temporal en los mismos tests(conjunto de tareas con habilidades auditivas)aplicados pre y post terapia del GE1 con el GE2. Sin embargo, se observó mejora en el desempeño de las pruebas de procesamiento temporal en GE2. **Conclusión:** La terapia fonológica combinada con el entrenamiento auditivo computarizado en niños con Trastorno Fonológico no evidenció diferencia estadísticamente diferente, sin embargo demostró influir en el aumento del desempeño de las pruebas de procesamiento temporal de estos niños cuando comparado al uso aislado de la terapia fonológica.

Palabras clave: Percepción del habla; Percepción auditiva; Patología del Habla y Lenguaje; Rehabilitación de los Trastornos del Habla y del Lenguaje.

Introduction

Phonological-based therapy has been an extremely effective method for the treatment of phonological disorders (PD) for many years[1]. PD are characterized by the presence of changes in speech performed by children after the period in which they were supposed to produce the contrasting sounds of the language, according to the adult target - according to age and regional variations. These difficulties may include errors in terms of production, perception or organization of phonemes at ages equal to, or greater than five years old[2].

PD is one of the most common speech pathologies among young children. Several studies have been carried out in the area, correlating the skills of phonological awareness, auditory discrimination, working memory, phonological memory, school difficulties and central auditory processing[3]; however, according to its traditional definition there is no apparent cause for this disorder. It is known that some factors may co-occur with the emergence of PD, such as family aspects and difficulties in relation to phonological memory[3].

There is scientific evidence that children with PD may present certain difficulties in processing the auditory information[3]. In parallel, some types of research have verified contributions of auditory training (AT) in the treatment of some speech pathologies, such as learning difficulties and hearing loss. In this sense, several studies have shown improvement in aspects related to speech production through the use of auditory training[4-8]. Thus, it is important to verify whether auditory training could optimize the therapeutic process of PD.

AT can improve the perception/sound manipulation, which reflect in the acquisition of absent or partially acquired phonemes in deviant speech. In agreement with this statement, there are investigations that have already shown that phonological therapy itself enables an improvement in auditory skills[5]. In addition, when AT is intended to be performed with children, it must be considered that AT needs to arouse the interest and motivation of the patient to perform the task, which is a facilitator for the achievement of the objective proposed in the training and for better therapeutic adherence[9].

Thus, the inclusion of new technologies in the daily lives of children, such as the use of computers, tablets and smartphones, may be an extremely useful resource and motivator in the therapeutic environment[10]. However, it is necessary to be cautious, as this is a new method that is used in the therapeutic approach, and needs to be analyzed and ratified regarding care during its use and the improvements in the quality of life of these children[11].

The use of new technologies, by approaching the reality in which most children are currently exposed, can turn the process of remediation of speech disorders shorter and more effective. Thus, with technological evolution, the speech therapist can register and manage the results, in addition to the therapeutic evolution individually, through softwares with internet access[10].

Some studies have been proving, for some time, the benefits of specific software for auditory training in cases of language difficulties, including changes in speech. Research that used the protocols of these types of software in children with language disorders showed some improvements in auditory skills and had significant differences in global language tests after the application of the protocols[10]. Such studies indicate that the application of these instruments is of great value for therapy with chil-

dren who have some difficulty related to language. However, the use of these tools must take place through the performance of monitored and programmed tasks, through specific software, which is in agreement with what is already proposed in phonological therapy.

Thus, this study aims to compare the result of purely phonological therapy with phonological therapy associated with computerized auditory training. This means that it is intended to verify whether the insertion of computerized auditory training will help to optimize the results of therapy in cases of PD.

Method

This research, according to the rules regulated by Resolution 196/1996 (BRASIL Resolution MS/CNS/CNEP nº. 196/96 of October 10, 1996), was approved by the Ethics and Research in Health Committee (CEP) of an Institution of Higher Education (IHE), with CAAE number 0202.0.243.000-11.

Six children diagnosed with PD participated in this study, aged between 6:00 and 7:11 years, monolingual Brazilian Portuguese speakers, right-handed, who did not present other speech disorders that interfered with speech production, such as voice disorders, orofacial motricity, hearing or other levels of language besides the phonological one, or even though neurological, cognitive or psychological alterations. In addition, all participants did not present a history of otitis media and they did not make use of medications that would affect sleep, wakefulness and attention. They all were students in regular elementary school, they had no history of bilingualism, they attended between the first and third year of school and they also presented low socioeconomic status.

To carry out the study of the six subjects, three received phonologically-based therapy, through the Model of minimal pairs, maximal or minimal oppositions, depending on the case, (severity of the disorder/number of altered phonemes)[12], which were named Study Group 1 (SG1) and the other three received phonological-based therapy associated with auditory training, being included in Study Group 2 (SG2). The selection of children for each group was carried out by drawing lots.

Regarding therapies, 25 sessions were held twice a week, lasting one hour, and the rooms used for care were not always the same, as it depended on the availability of rooms in the service on the day of the session. SG1 phonological visits were divided into 30 minutes of phonological therapy and the rest of the time was used with activities that did not present auditory stimulation, such as memory games, bowling and dominoes. SG2 had 30 minutes of phonological visit and the rest of the time, computerized auditory training was performed.

Regarding the visits that involved phonological rehabilitation, they were performed by students from the Speech, Language and Hearing Major, who were trained to perform the therapies in a uniform way, avoiding the bias of the therapist. However, aspects related to auditory training were always performed by the same graduated Speech, Language and Hearing professional, a specialist in the area. In addition, phonological therapies always followed the same model and chronogram, but they were programmed according to the alterations and difficulties of each subject.

After the composition of the research groups, the analysis of the phonetic and phonological systems was carried out, based on the results of the Child Phonological Assessment (CPA) [13], previously applied. Through this evaluation, the phonological inventory was described through the verification of acquired, partially acquired and not acquired phonemes, considering as an acquired phoneme (production equal to or greater than 80%), partially acquired (40% to 79% of production) and phoneme not acquired (less than or equal to 39%)[14].

In addition, the Percentage of Correct Consonants Revised (PCC-R) was also calculated to identify the severity of the phonological disorder, using PCC-R criterion in which distortions are not considered as errors, but based on in the calculation of PCC-R. This index considers the mild degree disorder (MD) between 86 and 100% of correct production, the mildly-moderate degree disorder (MMD) between 66% and 85%, the moderately-severe (MSD) between 51 and 65% and severe degree disorder (SD) less than 50%. Thus, the objective of the classification of the PD degree was to create the therapy groups (SG1 and SG2) in order that they were uniform.

All children in both groups present pure tone hearing thresholds equal to or less than 15 dB at frequencies from 250 to 8,000 Hz, bilaterally, with no evidence of conductive alterations either at the

time of assessment or in their health history. The auditory temporal processing tests were applied in a soundproof booth using a Fonix model FA-12 two-channel digital audiometer with TDH-39P headphones and Sony CD-player, model D-11 coupled to the audiometer, and they consisted of the following tests: duration pattern (DPT) and frequency pattern (FPT)[15] and GIN – Gap in Noise[16]. The tests were applied at 50 dB sensation level binaurally (DPT and FTP) and monaurally the GIN test. The method of application and analysis of the results was adopted as recommended by its proponents[15,16].

After the children were evaluated for phonological features and auditory temporal processing, the therapeutic process started. The three children who made up SG1 received phonological therapy, based on the Minimum Pairs Model - Maximum or Minimum Oppositions[12] according to the severity of the case, as this model does not work with phonological awareness or phonological processes, but with the idea of minimal contrasts – altered distinctive features.

This therapeutic model has the contrast between two words that differ in only one phoneme as a basic treatment procedure, which may differ in at least three dimensions: regarding the number of distinctive oppositions, in relation to the nature of feature distinction, and in terms of the relationship with the grammar of the child before treatment. The choice of phonemes always sought the greatest generalization, that is, the expansion of production and correct use of trained target-phonemes in other contexts or untrained environments.

The structure of the sessions consisted of five levels of training (Chart 1), for both groups, with a level of perception that focuses on sound identification and four levels of production: word imitation, independent naming, minimal pairs and sentences[1]. According to the progression of the child, which was verified in the surveys, the patient moved to the next level or remained at the worked level.

Chart 1. Structure of therapy sessions

Sessions	Phonological therapy stage SG1 and SG2	Placebo task stage SG1	Stage of auditory processing therapy SG2
1.__/__/__	Perception	Drawing and painting (free)	how many intervals how many sounds right in the correct place take if you can
2.__/__/__	Production Imitation of words	Memory game, Dominoes	how many intervals what sound did you hear follow the flute Left and right
3.__/__/__	Production Independent naming	Bowling and Drawing	what sound did you hear how many intervals follow the piano right in the correct place
4. __/__/__	Production Minimum pairs	Lynx, face to face	right in the crosshairs what sound did you hear follow the flute Left and right
5.__/__/__	Surveys	Free choice	Software evaluation

Source: the authors

As a consequence, when the child completed the perception level, there was verified some progression regarding the production level - word imitation, in order that the child produced the target sounds after the model of the therapist in 5 - 10 carefully selected words, which were not the same ones used in therapy. At the next level of production, independent naming, the child should produce the target sounds in the same set of stimuli, but without the adult model, if the child reaches at least 50% correction at this level, the child goes to the minimal pairs level.

At the minimal pairs level, the child had to produce the target sounds in five words during the

planned activities. The survey was carried out when the child reached 90% correct production of the target sound in a block of 20 to 30 attempts. The training reached the sentence production level for all sounds that had at least 50% correction during the survey, even when considering the untrained ones[1].

SG1 therapy session was distributed as follows: 30 minutes of phonological therapy and another 30 minutes of placebo task, that is, tasks that did not involve phonology stimulation strategies, phonological awareness and/or auditory stimulation tasks. On the other hand, SG2 was submitted to mixed therapy, that is, phonological therapy associated with auditory training, following the same models proposed for SG1, however, the final 30 minutes of the session was intended for auditory stimulation, performed with the *Escuta Ativa* software[17]. It was intended for children of the age group of this research, working exclusively on auditory skills through synthesized verbal and non-verbal stimuli.

The software offers a set of acoustic tasks designed to activate the auditory system and related systems in such a way that their neural bases and associated auditory behaviors are positively altered. The different activities are intended to improve auditory perception and provide organized, planned and measured training to be used by children, adolescents, adults and the elderly people.

In the auditory training, twelve activities worked on the following auditory skills: stimulation of auditory abilities of binaural interaction, figure-ground, temporal resolution, temporal standardization, discrimination, integration and binaural separation, and all tasks were presented with different levels of difficulty. In addition, regardless of the task being done, *Escuta Ativa* provides a control that allows the insertion of competitive background noise in each game and as a reward for the advances made by the patient, the software provides two "award" games with the aim to maintain the motivation and commitment of the player.

In order to obtain a better control of the results, the use of the software was adapted, as it is recommended that the tasks would be performed at home every day. On the other hand, for this study, the tasks were performed during therapy with the monitoring of the researcher, in order to not create bias, as some children could perform more activities than others at home.

All subjects received two weekly appointments of approximately one hour. The difference, as mentioned, was that SG2 received 30 minutes of care for the application of the central auditory processing therapy software, while SG1 performed the placebo tasks. Phonological surveys were carried out every five sessions to check the progress in phonological therapy. This structure was repeated for another five cycles until completing the 25 sessions. After this period, for ethical reasons, when necessary, the subjects continued to be assisted in the speech sector of the school clinic.

After the end of the period of 25 therapy sessions, all subjects underwent a new assessment of CAP and CPA. The results before and after therapy, for each subject, were compared in CAP assessments, in the PCC-R, and in the number of acquired phonemes. Thus, at the end of the initial and final evaluations, the number of acquired phonemes, the degree of severity obtained by the PCC-R, were correlated with the results of the GIN, FPT and DPT tests. Furthermore, these assessments were compared with each other and between SG1 and SG2.

Thus, after the end of collection, the data underwent statistical analysis. Frequency tables with absolute (n) and relative (%) frequency values of categorical variables and descriptive statistics of the numerical variable (GIN, FPT and DPT tests), with values of mean, standard deviation, minimum and maximum values and median were used to describe the profile of the sample according to the variables under study. However, to analyze the relationship between numerical variables, Spearman's correlation coefficient was used, due to the absence of normal distribution of the variables. The significance level adopted for the statistical tests was 5% ($P<0.05$).

Results

In this section, the results obtained in the study of the analyzed groups will be presented.

Table 1 below shows the comparisons of the numerical variables between the two groups, SG1 and SG2, with regard to the evolution of their performance in the GIN, named and whispering FPT and named DPT tests and whispering , in addition to analyzing the PCC-R and acquired phonemes. As can be observed, there was no statistically significant difference. However, it can be noted that there was an improvement in the mean of correct answers in the temporal tests, as well as the PCC-R and the number of acquired phonemes, when comparing the initial and final assessments of both groups. Although there is no statistically significant difference, SG2 obtained a proportionally greater increase in the mean of correct answers than SG1, especially in the FPT, DPT and GIN tests in the left ear (LE), as well as in the PCC-R.

Table 1. Comparison of results in temporal tests and in phonology between SG1 and SG2 in the pre-therapy period and between SG1 and SG2 in the post-therapy period

GROUP	VARIABLE	N	CORRECT ANSWERS AVERAGE	S.D.	MIN	MEDIAN	MÁX	P-VALUE*
SG1 – pre	*GIN*RE1	1	15.00	-	15.00	15.00	15.00	0.221
	*GIN*LE1	1	10.00	-	10.00	10.00	10.00	0.999
	NAMFPT1	3	57.78	29.12	33.33	50.00	90.00	0.275
	WHISPFPT1	3	65.55	26.73	40.00	63.33	93.33	0.127
	NAMDPT1	3	43.33	17.64	30.00	36.66	63.33	0.275
	WHISPDPT1	3	46.67	20.82	30.00	40.00	70.00	0.275
	PCC-R1	3	90.75	8.44	81.60	92.40	98.24	0.275
	AcqPhoneme1	3	17.33	0.58	17.00	17.00	18.00	0.814
SG1-post	*GIN*RE2	3	5.33	2.52	3.00	5.00	8.00	0.507
	*GIN*LE2	3	6.33	3.51	3.00	6.00	10.00	0.507
	NAMFPT2	3	67.77	38.63	23.33	86.66	93.33	0.507
	WHISPFPT2	3	72.22	37.17	30.00	86.66	100.00	0.827
	NAMDPT2	3	47.77	18.96	26.66	53.33	63.33	0.513
	WHISPDPT2	3	52.22	19.53	30.00	60.00	66.66	0.513
	PCC-R2	3	92.44	9.83	81.33	96.00	100.00	0.513
	AcqPhoneme2	3	18.67	0.58	18.00	19.00	19.00	0.099
SG2-pre	*GIN*RE1	2	5.00	4.24	2.00	5.00	8.00	
	*GIN*LE1	2	11.50	4.95	8.00	11.50	15.00	
	NAMFPT1	3	26.64	28.45	0.00	23.33	56.60	
	WHISPFPT1	3	31.10	31.66	0.00	30.00	63.30	
	NAMDPT1	3	21.09	23.61	0.00	16.66	46.60	
	WHISPDPT1	3	23.33	25.17	0.00	20.00	50.00	
	PCC-R1	3	80.00	6.24	73.00	82.00	85.00	
	AcqPhonemes1	3	15.00	5.20	9.00	18.00	18.00	
SG2-post	*GIN*RE2	3	5.33	5.77	2.00	2.00	12.00	
	*GIN*LE2	3	6.33	7.51	2.00	2.00	15.00	
	NAMFPT2	3	63.33	5.77	60.00	60.00	70.00	
	WHISPFPT2	3	78.86	15.78	66.60	73.33	96.66	
	NAMDPT2	3	39.99	6.68	33.30	40.00	46.66	
	WHISPDPT2	3	43.33	3.33	40.00	43.33	46.66	
	PCC-R2	3	84.77	14.42	68.70	89.00	96.60	
	AcqPhonemes2	3	15.33	4.62	10.00	18.00	18.00	

Caption: N: number of subjects who answered the test, SD: standard deviation, MIN: minimum, MAX: maximum, P-value* referring to the Kruskal-Wallis test for comparing the variables between the 2 groups, GINRE: Gap in Noise right ear, GINLE: Gap in Noise left ear, NAMFPT: Named Frequency Pattern Test, WHISPFPT: Whispered Frequency Pattern Test, NAMDPT: Named Duration Pattern Test, WHISPDPT: Whispered Duration Pattern Test, PCC-R: percentage of consonants correct -revised, AcqPhonemes: acquired phonemes. Number 1 indicates pre-therapy assessment, number 2 refers to post-therapy assessment.

Table 2 shows the comparison of numerical variables between pre and post-therapy assessments for SG1, in which there is no significant difference in any of the analyzed variables.

Table 3 analyzes the comparison of numerical variables between pre and post therapy assessments for SG2. As it can be observed, it is not possible to verify a significant difference in any of the analyzed variables.

In Tables 4 and 5, we observe the descriptive analysis of non-acquired and partially acquired phonemes for each subject of the studied groups, and when comparing the phonological systems of all subjects, it can be verified that most subjects present a non-acquired phoneme, with the exception of S1 of SG2, which has a more altered phonological system. Thus, from a total of the six children, after the 25 therapy sessions, four subjects did not acquire the absent phonemes, one from SG1 and the three from SG2, the other two children from SG1 acquired all the absent or partially acquired phonemes.

Table 2. Comparison of temporal processing and phonology results between pre and post therapy periods for SG1

VARIABLE	N	MEAN	S.D.	MIN	MEDIAN	MAX	P-VALUE*
*GIN*RE1	1	15.00	-	15.00	15.00	15.00	1.000
*GIN*RE2	1	5.00	-	5.00	5.00	5.00	
Difference	1	-10.00	-	-10.00	-10.00	-10.00	
*GIN*LE1	1	10.00	-	10.00	10.00	10.00	1.000
*GIN*LE2	1	6.00	-	6.00	6.00	6.00	
Difference	1	-4.00	-	-4.00	-4.00	-4.00	
NAMFPT1	3	57.78	29.12	33.33	50.00	90.00	0.750
NAMFPT2	3	67.77	38.63	23.33	86.66	93.33	
Difference	3	10.00	24.03	-10.00	3.33	36.66	
WHISPFPT1	3	65.55	26.73	40.00	63.33	93.33	0.750
WHISPFPT2	3	72.22	37.17	30.00	86.66	100.00	
Difference	3	6.67	16.67	-10.00	6.67	23.33	
NAMDPT1	3	43.33	17.64	30.00	36.66	63.33	1.000
NAMDPT2	3	47.77	18.96	26.66	53.33	63.33	
Difference	3	4.44	19.53	-10.00	-3.34	26.67	
WHISPDPT1	3	46.67	20.82	30.00	40.00	70.00	1.000
WHISPDPT2	3	52.22	19.53	30.00	60.00	66.66	
Difference	3	5.55	18.95	-10.00	0.00	26.66	
PCC-R1	3	90.75	8.44	81.60	92.40	98.24	0.500
PCC-R2	3	92.44	9.83	81.33	96.00	100.00	
Difference	3	1.70	1.94	-0.27	1.76	3.60	
AcqPhonemes1	3	17.33	0.58	17.00	17.00	18.00	0.500
AcqPhonemes2	3	18.67	0.58	18.00	19.00	19.00	
Difference	3	1.33	1.15	0.00	2.00	2.00	

Caption: N: number of subjects who answered the test, SD: standard deviation, MIN: minimum, MAX: maximum, P-value* referring to the Kruskal-Wallis test for comparing the variables between the 2 groups, GINRE: Gap in Noise right ear, GINLE: Gap in Noise left ear, NAMFPT: Named Frequency Pattern Test, WHISPFPT: Whispered Frequency Pattern Test, NAMDPT: Named Duration Pattern Test, WHISPDPT: Whispered Duration Pattern Test, PCC-R: percentage of consonants correct -revised, AcqPhonemes: acquired phonemes. Number 1 indicates pre-therapy assessment, number 2 refers to post-therapy assessment.

Table 3. Comparison of numerical variables between pre and post therapy assessments for SG2

VARIABLE	N	MEAN	S.D.	MIN	MEDIAN	MAX	P-VALUE*
*GIN*RE1	2	5.00	4.24	2.00	5.00	8.00	1.000
*GIN*RE2	2	2.00	0.00	2.00	2.00	2.00	
Difference	2	-3.00	4.24	-6.00	-3.00	0.00	
*GIN*LE1	2	11.50	4.95	8.00	11.50	15.00	0.500
*GIN*LE2	2	2.00	0.00	2.00	2.00	2.00	
Difference	2	-9.50	4.95	-13.00	-9.50	-6.00	
NAMFPT1	3	26.64	28.45	0.00	23.33	56.60	0.250
NAMFPT2	3	63.33	5.77	60.00	60.00	70.00	
Difference	3	36.69	33.30	3.40	36.67	70.00	
WHISPFPT1	3	31.10	31.66	0.00	30.00	63.30	0.250
WHISPFPT2	3	78.86	15.78	66.60	73.33	96.66	
Difference	3	47.76	38.65	3.30	66.66	73.33	
NAMDPT1	3	21.09	23.61	0.00	16.66	46.60	0.500
NAMDPT2	3	39.99	6.68	33.30	40.00	46.66	
Difference	3	18.90	30.23	-13.30	23.34	46.66	
WHISPDPT1	3	23.33	25.17	0.00	20.00	50.00	0.500
WHISPDPT2	3	43.33	3.33	40.00	43.33	46.66	
Difference	3	20.00	28.48	-10.00	23.33	46.66	
PCC-R1	3	80.00	6.24	73.00	82.00	85.00	0.750
PCC-R2	3	84.77	14.42	68.70	89.00	96.60	
Difference	3	4.77	9.47	-4.30	4.00	14.60	
AcqPhonemes1	3	15.00	5.20	9.00	18.00	18.00	1.000
AcqPhonemes2	3	15.33	4.62	10.00	18.00	18.00	
Difference	3	0.33	0.58	0.00	0.00	1.00	

Caption: N: number of subjects who answered the test, SD: standard deviation, MIN: minimum, MAX: maximum, P-value* referring to the Kruskal-Wallis test for comparing the variables between the 2 groups, GINRE: Gap in Noise right ear, GINLE: Gap in Noise left ear, NAMFPT: Named Frequency Pattern Test, WHISPFPT: Whispered Frequency Pattern Test, NAMDPT: Named Duration Pattern Test, WHISPDPT: Whispered Duration Pattern Test, PCC-R: percentage of consonants correct -revised, AcqPhonemes: acquired phonemes. Number 1 indicates pre-therapy assessment, number 2 refers to post-therapy assessment.

Table 4. Descriptive analysis of the percentage of correct answers of not acquired and partially acquired phonemes of the subjects in SG1

	PRE-THERAPY				POST-THERAPY			
	NOT ACQUIRED PHONEMES Phonemes (Frequency of production)		PARTIALLY ACQUIRED		NOT ACQUIRED PHONEMES		PARTIALLY ACQUIRED	
S1SG1	/S/	16%	-		-		-	
	/Z/	33,30%	-		-		-	
S2SG1	/ʒ/	20%	/ʃ/	50%	-		-	
S3SG1	/ɾ/	0%	-		/ɾ/	0%		

Caption: S1: subject 1 of SG1. S2: subject 2 of SG1. S3: subject 3 of SG1

Table 5. Descriptive analysis of the percentage of correct answers of not acquired and partially acquired phonemes of the subjects in SG2

	PRE-THERAPY				POST-THERAPY			
	NOT ACQUIRED PHONEMES		PARTIALLY ACQUIRED		NOT ACQUIRED PHONEMES		PARTIALLY ACQUIRED	
S1SG2	/g/	16%	/b/	73%	/d/	33%	/b/	50%
	/ʃ/	20%	/d/	50%	/z/	0%	/g/	55%
	/ʒ/	0%	/v/	62%	/ʃ/	0%	/v/	63%
	/ɾ/	10%	/z/	50%	/ʒ/	0%	/ɾ/	60%
	/ʎ/	0%	/l/	76%			/ʎ/	75%
S2SG2	-		/ɾ/	57%	-		/ɾ/	50%
S3SG2	/ɾ/	0%	-		/ɾ/	0%	-	

Caption: S1: subject 1 of SG2. S2: subject 2 of SG2. S3: subject 3 of SG2.

Discussion

When analyzing SG1 and SG2 before and after therapy, there was no statistically significant difference between the groups in relation to temporal processing skills, assessed by the GIN, FPT and DPT tests, as well as for the PCC-R and the number of phonemes acquired.

However, when analyzing in general the results of the CAP pre and post therapy, there was an improvement in the performance in the temporal processing tests, however, it is observed that still with lower scores. Similar evidence was found in the description of audiological findings of the peripheral and central auditory system including the FPT, DPT and GIN in three children with phonological disorder[18].

One aspect that is observed in this study is the lowered performance in both the whispering and naming tasks in both moments, pre and post therapy. The same was not observed in a study of typically developing children in which the whispering response was superior and above 90% of correct answers at 7 years old, while the verbal response showed an increase in performance with increasing age[19].

Another aspect that may represent an improvement in the responses is that the difference between the results of FPT and DPT between pre and post therapy in SG2 were greater than in SG1, although GS1 presents a performance below expectations for their age, it is even closer to this normality than for SG2. On the other hand, when analyzing Tables 2 and 3, it is observed that SG2 in the post-therapy period is close to the performance of SG1. It can be inferred that there was a benefit in SG2 in the combined intervention of auditory and phonological training, although this was not statistically evidenced, maybe due to the limitation of the sample number. Aspect to be investigated in the continuity of the study.

According to the proponent, the standard for the DPT test is 67% in adults, and at 9 years old children would already present similar answers; however, a study[4] that evaluated children with typical development verified an average of 9% of correct answers naming and whispering at 7 years old, and 13% naming and 15% whispering at 8 years old. In this research, intermediate results were found, worse than the standard, but better than the study that we have cited. The aforementioned author found a great variability in the responses of the DPT test in children, and a possible justification lies in the fact that the test tasks involve more elaborate cognitive functions of attention and memory, which are not acquired homogeneously in the development of the children. There is a possibility that the DPT requires skills that are more intensely influenced by the learning processes and, therefore, also have more influence on the environment than the FPT[19].

Regarding the GIN test, low performance was verified among children in both groups, taking as a mean reference 5.0 ms with a standard deviation of 1.0 ms in adults[16], which is the same recommended in children in different studies with children typical in Brazil[20-22]. Even with no significant difference between pre and post-therapy in both groups, the scores obtained in the post-therapy assessment were lower in ms than in the pre-therapy assessment, suggesting an improvement in the performance of the temporal resolution ability. A study on the reproducibility of the GIN test observed that there is no difference in performance between the test and retest in normal hearing individuals[23], evidencing that it is a test with reliability.

A low performance on the GIN test was also noticed in 83.33% of children with phonological disorder in a descriptive study[24] of six children, 66.67% with medium severity and 33.33% with medium-moderate degree of phonological disorder.

In a recent systematic review with meta-analysis[25] it was observed that there are high sensitivity and specificity indices in the GIN test to identify individuals with neuro-auditory damage. This evidence strengthens the GIN test as a powerful clinical tool to reliably investigate temporal resolution dysfunction across languages and cultures.

In an international study, the authors found significant results[8] in the use of AT in cases of PD. In this study, auditory training was applied to children with PD and CAP disorder, and the authors obtained better results both in cases of PD and in cases where CAP deficit coexists with PD. In addition, the authors also report that AT can be used as a supportive therapy for phonological therapy.

A similar study applied formal auditory training, in which stimuli are acoustically controlled, and informal training, which also involves the stimulation of auditory skills, but without requiring acoustic control of the environment and the stimuli presented. The study verified the difference

between formal and informal training for CAP in a group of children with PD; however, the aim was to verify the performance in temporal processing of the subjects and not questions about phonology. The research did not find statistically significant results, but both formal and informal training provided improvement in temporal processing skills and in CAP[6].

There is another study that made use of computerized auditory training to investigate its effects in children with CAPD with typical and atypical phonological systems. As a result, it was found in both groups of this research, after computerized training, significant improvement in auditory skills of recognition of non-verbal sounds in directed listening and figure-ground for such sounds (Non-Verbal Dichotic Test - NVDT) and temporal resolution (Random Gap Test Detection - RGTD)[11].

Another study[4] verified the effectiveness of AT in children with central auditory processing disorder (CAPD), even after one, two or three years after the end of auditory training. Most subjects, after eight weeks of therapy, achieved results within the normal range. The benefits of AT in cases of CAPD have already been mentioned by some studies[5], however, there are not many reports of the results of AT in cases of PD, as in the present study.

Another study verified the use of experimental therapy with the use of a computer in cases of PD in comparison to standard therapy without a computer. The results were statistically significant, being that the group that used experimental therapy presented better results[2].

The poor performance in temporal processing tasks in most subjects, even after the AT, confirms the importance of perceiving and sequencing patterns of sounds. For the acquisition and understanding of language to occur correctly, it is necessary for the child to be able to perceive the acoustic properties of speech and that these can be reduced to the basic components of duration and frequency.

Such results in the CAP assessment might be related to limitations in the ability to quickly discriminate and classify verbal auditory stimuli, which would lead to difficulties in processing linguistic information at higher levels, such as in verbal comprehension. Then, if the child understands the sound in a distorted way, he/she will create different registers of the target phonemes and, consequently, the correct production will also be affected.

Changes in temporal processing in children with PD can be explained according to the mentioned studies[6,11,18-22,24,26], due to the fact that these children need more time to detect the time intervals between acoustic stimuli than children with normal speech development. This same justification can also explain the fact that children with PD present some difficulty in producing sounds correctly, which is in agreement with what was observed in the results of the GIN test.

On the other hand, there is evidence that the degree of severity of phonological disorders may be related to the presence of alterations in the central auditory processing[26] and, in this study, the children presented mild phonological disorders.

In the analysis of the results, it was found that four research subjects did not acquire the missing phonemes in their phonological system. Of these children, one was included in SG1 and the other three in SG2. However, the other two children in SG1 managed to acquire all the phonemes that were absent and partially acquired.

Furthermore, it was verified that of the three children in SG2, two presented the phoneme /r/ as the only alteration in the phonological system as non-acquired. These two subjects during the AT showed greater difficulty in performing the auditory tasks, also not evolving in the degree of difficulty in most activities proposed by the software, but mainly in dichotic tasks.

The /r/ phoneme is the most complex in the phonological system, requiring more accurate processing and more time to pass production and automation[7]. This data, added to the difficulty in performing the temporal processing tasks, could justify the difficulty of the subjects with the production and automation of the mentioned phoneme.

Thus, based on these results, we observed that there was no statistically significant difference between the therapeutic models that were used. However, the results found may have been influenced by the small number of subjects and the reduced time of auditory stimulation, since the indicated would be daily auditory training, as well as the little altered phonological system of most of the children studied.

Conclusion

Based on the results that were obtained, it is possible to conclude that phonological therapy

combined with computerized auditory training in children with PD did not show a statistically different difference, but it was shown to influence the increase in the performance of temporal processing tests in these children when compared to the isolated use of the phonological therapy.

It is suggested that further research should be carried out on this topic, with a greater number of subjects and longer auditory stimulation time, in order to verify other factors that impact the influence of computerized AT in cases of PD.

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