Original Article

Artigo Original

Temporal processing in children with phonological disorders submitted to auditory training: a pilot study

Processamento temporal de crianças com transtorno fonológico submetidas ao treino auditivo: estudo piloto

Nadia Vilela[1]
Haydée Fiszbein Wertzner[2]
Seisse Gabriela Gandolfi Sanches[2]
Ivone Ferreira Neves-Lobo[2]
Renata Mota Mamede Carvallo[2]

Keywords

Hearing tests
Auditory perception
Hearing
Hearing disorders/rehabilitation
Articulation disorders
Neuronal plasticity
Child

ABSTRACT

Purpose: This study compared the temporal processing performance of children with phonological disorders submitted to formal and informal auditory training. **Methods:** Fifteen subjects with phonological disorder (pure tone thresholds ≤20 dBHL from 0.50 to 4 kHz, and age between 7 years and 10 years and 11 months) were evaluated, divided into three groups: Control Group: five subjects (mean age 9.1 years) without auditory processing disorder, who passed through two evaluations of the auditory processing at intervals of six to eight weeks and without any intervention; Formal Training Group with five subjects (average 8.3 years) with auditory processing disorder submitted to eight sessions of formal training; and Informal Training Group, with five subjects (average 8.1 years) with auditory processing disorder submitted to eight sessions of informal training. **Results:** After eight sessions the formal training group showed an improvement of 8% and the informal training group of 22.5% in comparison with the pitch pattern sequence test. For the duration pattern sequence test, the average of the formal training group improved by 12.9% and the informal training group by 18.7%. There was no statistical difference between the means obtained by both groups after intervention, neither in the pitch pattern nor in the duration pattern sequence test. **Conclusion:** Although the results did not present significant differences, this pilot study suggests that both formal and informal trainings provide improvement in the temporal processing abilities of children with phonological and auditory processing disorders.

Descritores

Testes de audição
Percepção auditiva
Audição
Transtornos da audição/reabilitação
Transtornos da articulação
Plasticidade neuronal
Criança

RESUMO

Objetivo: Comparar o desempenho em processamento temporal de crianças com transtorno fonológico submetidos a treino auditivo formal e informal. **Métodos:** Quinze indivíduos com transtorno fonológico (limiares tonais ≤20 dBNA de 0,50 a 4 kHz e idades entre 7 anos e 10 anos e 11 meses) foram avaliados e divididos em três grupos: Grupo Controle – composto por cinco indivíduos (média de idade de 9,1 anos) sem transtorno do processamento auditivo, que passaram por duas avaliações do processamento auditivo (central) com intervalo de seis a oito semanas, sem receber qualquer intervenção; Grupo Treino Formal – composto por cinco indivíduos (média de idade de 8,3 anos), com transtorno do processamento auditivo, submetidos a oito sessões de treino formal; e Grupo Treino Informal – composto por cinco indivíduos (média de idade de 8,1 anos) com transtorno do processamento auditivo, submetidos a oito sessões de treino informal. **Resultados:** Após oito sessões, o grupo treino formal apresentou melhora de 8% e o grupo treino informal de 22,5% no que se refere ao teste padrão temporal de frequência. Para o teste padrão temporal de duração, o grupo treino formal melhorou 12,9% e o grupo treino informal 18,7%. No desempenho nos testes padrão de frequência e padrão de duração, não houve diferença estatística entre as médias obtidas pelos dois grupos após a intervenção. **Conclusão:** Embora os resultados não tenham apresentado significância estatística, o estudo piloto apresentado sugere que ambos os treinos, formal e informal, proporcionam melhora das habilidades de processamento temporal em crianças com transtorno fonológico e do processamento auditivo.

Correspondence address:
Nadia Vilela
R. Dr. Ruy Vicente de Mello, 140, Cidade Universitária, Campinas (SP), Brasil, CEP: 13083-745.
E-mail: nadiavilela@usp.br

Received: 11/24/2011

Accepted: 2/8/2012

Study developed at the Department of Physical Therapy, Speech-Language Pathology and Audiology, and Occupational Therapy, School of Medicine, Universidade de São Paulo – USP – São Paulo (SP), Brazil.
Conflict of interests: None
(1) Graduate Program (Masters degree) in Rehabilitation Sciences, School of Medicine, Universidade de São Paulo – USP – São Paulo (SP), Brazil.
(2) Department of Physical Therapy, Speech-Language Pathology and Audiology, and Occupational Therapy, School of Medicine, Universidade de São Paulo – USP – São Paulo (SP), Brazil.

INTRODUCTION

The assessment of the Central Auditory System have aroused the interest of researchers since the mid-1950s[1]. According to the American Speech-Language-Hearing Association (ASHA), Central Auditory Processing (CAP) involves the mechanisms of the auditory system with which the nervous system deals with sound information, whether verbal or nonverbal. If a person has preserved auditory sensitivity but difficulty in one or more listening abilities necessary for the auditory processing, a Central Auditory Processing Disorder (CAPD) is characterized[2].

The auditory temporal processing refers to how the auditory system deals with the time differences of the acoustic stimulus. In this perspective, authors have defended its close relationship with the comprehension of speech. This relationship can be established because, in speech, there is rapid transition of acoustic elements, and these changes must be properly analyzed by the auditory system[3-5].

The auditory brainstem can be modified by short and long-term auditory experiences initiated in childhood[6]. It is possible to improve the functions of the auditory system regarding the resolution of acoustic signals by training listening abilities, which is called auditory training[7-9]. Such training can be formal or informal. In formal training, acoustically controlled activities are proposed and applied within a soundproof booth by a qualified professional. Informal training also involves stimulation of auditory skills, but without requiring acoustic control of the environment and stimuli. Both formal and informal training are based on neural plasticity, which is the ability of the central nervous system (CNS) to undergo neurophysiologic changes based on sensory experiences[10-14]. Studies have demonstrated the benefits provided by temporal auditory processing training[9,15].

Considering the development of language, Ingram[16] states that it is based on the auditory perception and production of speech sounds that a child learns the rules of her/his native language and appropriates a phonological system of contrasts.

The phonological disorder is a speech and language disorder that is very common in the pediatric population and has an uneven manifestation. Theoretical models that study the development of speech, supported by the Dynamic Systems Theory, indicate that there is an interrelationship between motor, linguistic and auditory-cognitive speech processes, emphasizing the connection between the action (oral motor gesture) and the perception caused in the subject. This connection develops the kinesthetic and auditory monitoring of the articulatory gesture[17-21]. Evidences support the interactions between motor, auditory and somatosensory systems that involve the formation of neural mappings [19]. Some authors believe there may be a close relationship between CAPD and speech disorders because the first interferes with the stability of the phonemic representation in the brain and with speech perception, making the learning of phonology, syntax and semantics difficult[4,5].

CAP studies have shown positive results in cases of patients with CAPD who were submitted to informal auditory training[9,12]. However, studies that compare these types of intervention (formal and informal CAP training) are still needed, in order to verify their real effects, results, and ideal situations of use.

Thus, the main objective of this pilot study was to determine the variations in temporal processing performance of children with phonological and CAP disorders, before and after formal and informal auditory training.

METHODS

Approval for this study was granted by the local ethics committee (0807/08). Written informed consent was obtained from the parent or guardian of each child tested in this study.

The first inclusion criteria for all subjects was the presence of alterations in the phonological test[22] of the ABFW Child Language Test, characterized by omission and/or substitution of phonemes related to the presence of phonological processes, with or without alterations in written language, and in the absence of concomitant syntactic, semantic or pragmatic alterations. The subjects were all volunteers invited to participate in this study. Participants were 15 children with phonological disorder and ages between 7 years and 10 years and 11 months, who were submitted to an audiological assessment that included CAP tests and presented hearing thresholds ≤20 dB in the frequencies from 0.5 to 4 kHz. The results of the CAP assessment determined the inclusion of children in one of the three groups in this study.

After signing the informed consent, subjects underwent tympanometry (middle ear analyzer Interacoustics® AT235h – microprocessor and equipped with two-frequency impedance probe tone: 226 Hz and 1 kHz). The equipment was used for automatic tympanometric measurements and for measures of ipsilateral acoustic reflex. Subjects were also submitted to pure tone audiometry for frequencies ranging from 0.5 to 4 kHz, using Audiometer GSI 61 – Grason Stadler® (ANSI S3 0.6-1989, ANSI S3 .43-1992, IEC 645-1.1992, IEC 645-2, 1993, ISO 389, UL 544) and TDH 50P phones.

The tests used to evaluate CAP were: a) Figure Identification (FI) with competitive ipsilateral noise (signal to noise ratio = +20; normal range: 90%) (Portuguese version[23]); b) Dichotic Digits test (DD) (Portuguese version[23]) (normal range: between 7 and 8 years of age, 85% in the right ear and 82% in the left ear; between 9 and 10 years, 90% in both ears; from 11 years on, 93% in both ears); c) Pitch Pattern Sequence test (PPS)[24]; and d) Duration Pattern Sequence test (DPS)[24] (normal standards for both tests were based on the results of Balen[25]).

For the evaluation, a compact disc (CD) with the stimuli was played on a CD player coupled to the audiometer.

According to the results from the CAP evaluation, children were divided into three groups:

- Control Group (C): composed of five male subjects without CAPD, with mean age of 9.1 years;
- Formal Auditory Training Group (FT): composed of five subjects (two female and three male) with mean age of 8.3 years and altered results in at least two behavioral CAP tests;
- Informal Auditory Training Group (IT): composed of five subjects (two female and three male) with mean age of 8.1

years and altered results in at least two behavioral CAP tests.

All children in this study were submitted to an initial CAP assessment (CAP1). Between six and eight weeks after, all subjects were submitted to a second CAP evaluation (CAP2), without having received any intervention. The interest in carrying out two CAP evaluations with an interval of time between six to eight weeks was directed to an attempt to identify eventual performance variations, even in the absence of intervention.

The placement of each child into the groups C, FT or IT was based on the results of the CAP2, according to the following criteria. To be included in the C group, the child could have altered results in only one task of the battery of CAP tests. Children who were included in the formal training (FT) group had altered results in at least two tests, both in the CAP1 and the CAP2. These children were subjected to eight sessions of formal auditory training, conducted according to principles previously proposed[26]. After the completion of formal training, this group was submitted to a third CAP evaluation (CAP3), in order to verify performance modifications. Children included in the informal training (IT) group also showed altered results in at least two tests, both in the CAP1 and the CAP2. These children received eight sessions of informal auditory training. All activities were carried out using headphones adjusted to 60 dBA (measurements taken in a soundproof booth with digital sound level meter – brand Instrutherm®, model DEC 460 – with frequency range from 31.5 Hz to 8 kHz) in a quiet therapy room, and followed an informal auditory training program elaborated specifically for this study. The characteristics of the stimulation program are in Appendix 1. After the completion of informal training, this group was also submitted to the CAP3.

For data analysis, the means of both research groups (FT and IT) in all three evaluations were compared by using the multivariate analysis of variance with repeated measures, in order to compare the mean of the third evaluation with those of previous reviews, and compare the means of the two groups in the third evaluation. The method of Bonferroni multiple comparisons was applied to find differences between the means. The significance level was set at 0.05.

As the interest of this research was on temporal auditory processing, the dependent variables studied were the results obtained in the PPS and DPS tests.

RESULTS

Analysis of the results obtained in the Pitch Pattern Sequence test (PPS)

Observed values of descriptive statistics for the percentage of correct responses in the PPS by group and assessment are found in Table 1. Mean values in the Control Group were higher than in the FT and IT groups in the first two evaluations. Mean values of the IT group were higher in the third evaluation than those observed in previous assessments, although without statistical significance.

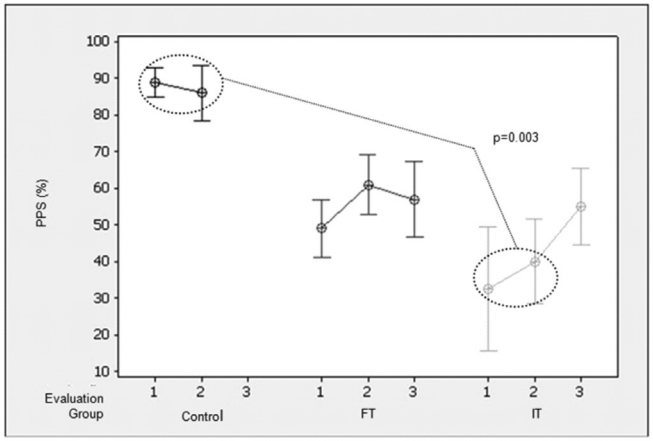
The comparison between the three groups in the first two evaluations (Figure 1) showed that there was no difference between the mean scores on the PPS test in both evaluations (p=0.165), regardless of the group (p=0.349). Moreover, the mean scores were different in all three groups, and the difference between them was independent of the evaluation (p=0.349). No difference was found between the mean scores of the C and FT groups on the PPS in the first two evaluations (p=0.055). The mean of the C group was higher than the IT mean (p=0.003), and there was no difference between the mean scores of the FT and IT groups (p=0.356), still considering the first two assessments. Thus, one can conclude that there was no difference between the means of the FT and IT groups on the PPS, and their means are smaller than that of the C group, although this difference was not significant compared to the FT group.

The analysis of the FT and IT groups showed no difference between the mean scores in all evaluations (p=0.076), regardless of the group (p=0.323) (hence, there was no difference between the mean in the third evaluation and the means in the first two). There was also no difference between the mean scores of the groups (p=0.243), regardless of the evaluation (p=0.323) (thus,

Table 1. Correct responses in the PPS test by group and evaluation

Evaluation	Group	n	Mean	SD	Minimum	Median	Maximum
CAP1	C	5	89.0	8.9	80.0	90.0	100.0
	FT	5	49.0	17.8	20.0	55.0	65.0
	IT	4	32.5	34.0	0.0	25.0	80.0
	Total	14	58.6	31.5	0.0	62.5	100.0
CAP2	C	5	86.0	16.7	60.0	90.0	100.0
	FT	5	61.0	18.5	30.0	65.0	75.0
	IT	5	40.0	25.7	15.0	30.0	70.0
	Total	15	62.3	27.3	15.0	65.0	100.0
CAP3	FT	5	57.0	23.1	30.0	65.0	80.0
	IT	5	55.0	23.2	15.0	60.0	75.0
	Total	10	56.0	21.8	15.0	62.5	80.0

Note: CAP1 = first central auditory processing assessment; CAP2 = second central auditory processing assessment; CAP3 = third central auditory processing assessment; C = control group; FT = formal training group; IT = informal training group; SD = standard deviation



Note: 1 = first evaluation of the central auditory processing (CAP1); 2 = second evaluation of the central auditory processing (CAP2); 3 = third evaluation of the central auditory processing (CAP3)

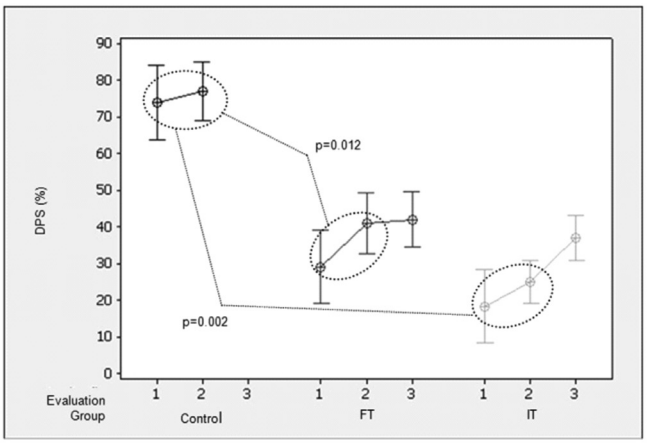
Figure 1. Mean ± standard error of the percentage of correct responses in the Pitch Pattern Sequence test by group and evaluation.

there was no difference between the means of the FT and IT groups in the third evaluation).

Analysis of the results obtained in the Duration Pattern Sequence Test (DPS)

The values of the descriptive statistics in Table 2 are similar to those observed in the analysis of the PPS: the mean score was higher in the C group than in the other two groups, and the means of the FT and IT groups tended to increase along the evaluations.

There was no difference between the mean percentage of correct answers in the first two evaluations (p=0.151), regardless of the group (p=0.511) (Figure 2). Moreover, the mean percentages of correct responses in the DPS test were different in all three groups (p=0.001), regardless of the group (p=0.511). Further analysis showed that the mean of the C group was higher than that of the FT (p=0.012) and the IT (p=0.002) groups, and there was no difference between the means of the FT and IT (p=0.435) groups.



Note: 1 = first evaluation of the central auditory processing (CAP1); 2 = second evaluation of the central auditory processing (CAP2); 3 = third evaluation of the central auditory processing (CAP3)

Figure 2. Mean ± standard error of the percentage of correct responses in the Duration Pattern Sequence test by group and evaluation.

The results obtained from analyzing the performances of the FT and IT groups showed that there was no difference between the mean percentage of correct responses in the DPS in all three evaluations (p=0.096), regardless of the group (p=0.615) (thus, there was no difference between the mean in the third evaluation and the means in the first two). Furthermore, no difference was found between the means of both groups (p=0.131), regardless of the evaluation (p=0.615) (hence, there was no difference between the means of the FT and IT groups in the third evaluation).

DISCUSSION

The present study shows that both formal training

Table 2. Correct responses in the DPS test by group and evaluation

Evaluation	Group	n	Mean	SD	Minimum	Median	Maximum
CAP1	C	5	74.0	22.7	40.0	80.0	100.0
	FT	4	29.1	20.3	1.5	32.5	50.0
	IT	3	18.3	17.6	0.0	20.0	35.0
	Total	12	45.1	32.0	0.0	37.5	100.0
CAP2	C	5	77.0	17.9	55.0	70.0	100.0
	FT	5	41.0	18.8	10.0	45.0	60.0
	IT	3	25.0	10.0	15.0	25.0	35.0
	Total	13	51.2	27.1	10.0	50.0	100.0
CAP3	FT	5	42.0	16.8	30.0	35.0	70.0
	IT	5	37.0	14.0	25.0	30.0	60.0
	Total	10	39.5	14.8	25.0	32.5	70.0

Note: CAP1 = first central auditory processing assessment; CAP2 = second central auditory processing assessment; CAP3 = third central auditory processing assessment; C = control group; FT = formal training group; IT = informal training group; SD = standard deviation

and informal training were able to provide qualitative improvement in the performance of children with regard to the auditory ability of temporal ordering and inter-hemispheric transfer.

Considering the performance of children in the PPS test, it can be observed that the means obtained in PAC3 for FT and IT groups were closer than the means obtained for the same groups in PAC1, although without statistical significance.

Considering subjects' performance in the PPS test, it must be noticed that, in the IT group, one child was unable to perform the test during the first assessment (CAP1), and started to respond only from the CAP2 on.

Considering the performance of the children in the DPS test, it must be emphasized that there were also children who were not able to carry out the initial assessment (CAP1) (one child in the FT group and two in the IT group) and in CAP2 (the same two children of the IT Group). The analysis of this data, separately, gives us the idea that the children who participated in the research improved in temporal ordering and inter-hemispheric transfer, once they had not been able to perform the task and later they could do it.

Unlike what happened in the PPS test, the performance of the C group in the DPS test did not appear more homogeneous than that of the other groups. Taking into account the comparison of the normal range between the PPS and DPS tests[26], it can be concluded that Portuguese-speaking children have better performance in the PPS test. This might be why even the performance of the C group was also heterogeneous; these findings corroborate the results of another study[27].

In general, the responses of the children in the FT and IT groups in the three CAP evaluations (1, 2 and 3) were very heterogeneous. These data agree with the findings of another study[28] that also found enough variability in the responses of children between 7 years and 11 years and 11 months.

Considering that the individuals in our study had phonological disorder and that this diagnosis can lead to learning difficulties, one could suggest that the participating children also showed delayed maturation of auditory skills, as suggested by some authors[29].

Although in the DPS test the performance of the IT group was worse than the FT group in the initial assessment (CAP1), no significant difference was observed between these two groups. However, both groups differed from the C group. After the auditory training, neither the FT nor the IT groups showed inter-groups differences, but one can observe that the difference between the means of these two groups decreased after the auditory training (Table 2). The FT group did not show performance improvement after the auditory training, whereas the IT group demonstrated greater ability to accomplish the task of temporal ordering and inter-hemispheric transfer after the training, even though this improvement was not significant. The results from this pilot study may provide us evidence that the differences observed could present statistical significance with a larger sample.

The results obtained reinforce the need of early intervention in children with phonological and auditory processing disorders, since both disorders hinder the learning of reading and writing and, hence, the academic performance of these children.

CONCLUSION

Both formal and informal training expand the intervention approaches in speech therapy for children with phonological disorders associated with auditory processing disorder. The results suggest that children with phonological disorders associated with auditory processing disorder benefit from additional sessions of auditory training.

Although the improvement of the auditory abilities of temporal resolution and inter-hemispheric transfer has not been statistically proved in this pilot study, the increase in the mean percentage of correct responses suggests that a larger sample could provide important changes.

ACKNOWLEDGMENTS

We thank the São Paulo Research Foundation (*Fundação de Amparo à Pesquisa do Estado de São Paulo* – FAPESP) for the financial support granted for this study (process 2008/07652-5).

REFERENCES

1. Bocca E, Calearo C, Cassinari V. A new method for testing hearing in temporal lobe tumours: preliminary report. ActaOtolaryngol. 1954;44(3):219-21.
2. American Speech-Language-Hearing Association. Central auditory processing: current status of research and implications for clinical practice. Am J Audiol. 1996;5(2): 41-54.
3. Hirsh IJ. Auditory perception of temporal order. J AcoustSoc Am. 1959;31(6):759-67.
4. McArthur GM, Bishop DVM. Speech and non-speech processing in people with specific language impairment: a behavioral and electrophysiological study. Brain Lang. 2005;94(3):260-73.
5. McArthur G, Atkinson C, Ellis D. Atypical brain responses to sounds in children with specific language and reading impairments. Dev Sci. 2009;12(5):768-83.
6. Song JH, Skoe E, Wong PC, Kraus N. Plasticity in the adult human auditory brainstem following short-term linguistic training. J CognNeurosci. 2008;20(10):1892-902.
7. Chermak GD, Musiek FE. Auditory trianing: principles and approaches for remediating and managing auditory processing disorders. Semin Hear. 2002;23(4):297-308.
8. Zhou X, Merzenich MM. Developmentally degraded cortical temporal processing restorted by training. Nat Neurosci. 2009;12(1):26-8.
9. Murphy CF, Schochat E. Generalization of temporal order detection skill learning: two experimental studies of children with dyslexia. Braz J Med Biol Res. 2010;13(4):359-66.
10. Musiek FE, Berge B. A neuroscience view of auditory training/ stimulation and central auditory processing disorders. In: Masters MG, Stecker NA, Katz J, editors. Central auditory processing disorders: mostly management. Boston: Allyn& Bacon; 1998. p.15-32.
11. Kraus N. Speech sound perception, neurophysiology, and plasticity. Int J PediatrOtorhinolaryngol. 1999;47(2):123-9.
12. Fujioka T, Ross B, KakigiI R, Pantev C, Trainor LJ. One year of musical training affects development of auditory cortical-evoked fields in young children. Brain. 2006;129(Pt 10):2593-608..
13. Moore DR. Auditory processing disorders: acquisition and treatment. J CommunDisord. 2007;40(4):295-304..
14. Tremblay K. Training-related changes in the brain: Evidences from human auditory-evoked potencial. Semin Hear. 2007;28(2):120-32.
15. Skoe E, Kraus N. Hearing it again and again: On-line subcortical plasticity in Humans. PloS ONE. 2010;5(10):e13645.
16. Ingram D. Phonological disability in children. London: Edward Arnold. 1976.

17. Kent RD. Research on speech motor control and its disorders: a review and prospective. J CommunDisord. 2000;33(5):391-427, quiz 428.
18. Guenther FH. Cortical interactions underlying the production of speech sounds. J CommunDisord. 2006;39(5):350-65..
19. Smith A. Development of neural control of orofacial movements for speech. In: Hardcastle WJ, Laver J, Gibbon FE. The handbook of phonetic sciences, 2nd ed. New York: Wiley-Blackwell; 2010.
20. Goffman L, Gerken L, Lucchesi J. Relations between segmental and motor variability in prosodically complex nonword sequences. J Speech Lang Hear Res. 2007;50(2):444-58.
21. Munhall KG. Functional imaging during speech production. Acta Psychol (Amst).2001;107(1-3):95-117.
22. Wertzner HF. Fonologia. In: Andrade CRF, Befi-Lopes DM, Fernandes FDM, Wertzner HF. ABFW – Teste de Linguagem Infantil nas Áreas de Fonologia, Vocabulário, Fluência e Pragmática. 2a ed. Carapicuíba: Pro Fono. 2004. p. 5-31.
23. Pereira LD, Schochat E. Testes auditivos comportamentais para avaliação do processamento auditivo central. Barueri (SP): Pró-Fono; 2011.
24. Evaluation manual of pitch pattern sequence and duration pattern sequence. Missouri: Auditec;1997.
25. Balen AS. Reconhecimento de padrões auditivos de frequência e de duração: desempenho de crianças escolares de 7 a 11 anos [tese]. São Paulo: Universidade de São Paulo; 2001.
26. Musiek FE, Schochat, E. Auditory training and central auditory processing disorders – A case study. Semin Hear. 1998;19(4):357-66.
27. Frederigue-Lopes NB, Bevilacqua MC, Samishima K, Costa AO. Desempenho de crianças normais em testes temporais auditivos em campo livre. Pro-Fono. 2010;22(2):83-8.
28. Schochat E, Rabelo CM, Sanfins MD. Processamento auditivo central: testes tonais de padrão de frequência e duração em indivíduos normais de 7 a 16 anos de idade. Pro-Fono. 2000;12(2):1-7.
29. Neves IF, Schochat E. Auditory processing maturation in children with and without learning difficulties. Pro-Fono. 2005;17(3):311-20.

Appendix 1. Description of the CD tracks for the informal training group

Auditory ability	Tr.	Number of stimuli	S/N	BN	Duration (ms)	ISI (ms)	Pitch (Hz)	Task
TO and ITr.	1	4 sets of 2 stimuli	--	--	200	200	≈1000 and ≈1400	Differentiate 2 sounds and/or name them
	2					100		
	3	14 sets of 3 stimuli	--	--	450	200		Ordering the stimuli
	4				350			
	5				250			
	6				150			
	7				100			
	8	4 sets of 2 stimuli	--	--	400 and 200	250	≈1000	Differentiate 2 sounds and/or name them
	9					200		
	10	14 sets of 3 stimuli	--	--		500		Ordering the stimuli
	11					400		
	12					300		
	13					200		
	14					150		
VC	15	100 words distributed in 5 SC	+20	WN	--	--	--	Signal to each word of a SC
	16		+5					
	17		0	MB				
	18		-15					
NVC	19	33 NVS distributed in 5 SC	+20	ST	--	--	--	Identify stimuli of a SC and name them
	20		+5					
VFG	21	100 words distributed in 5 SC	0	WN	--	--	--	Signal to each word of a SC
	22		-15					
NVFG	23	33 NVS distributed in 5 SC	0	ST	--	--	--	Identify stimuli of a SC and name them
	24		-15					

continue...

... continuation

Auditory ability	Tr.	Number of stimuli	S/N	BN	Duration (ms)	ISI (ms)	Pitch (Hz)	Task
C + VM	25	8 sets of 4 stimuli (= SC)	+20	WN	--	--	--	Repeat the sequence heard in the same order
	26		+5					
	27		0	MB				
	28		-15					
	29	8 sets of 4 stimuli (≠ SC)	+20	WN				
	30		+5					
	31		0	MB				
	32		-15					
	33	8 sets of 5 stimuli (= SC)	+20	WN	--	--	--	
	34		+5					
	35		0	MB				
	36		-15					
	37	8 sets of 5 stimuli (≠ SC)	+20	WN				
	38		+5					
	39		0	MB				
	40		-15					
FG + VM	41	8 sets of 4 stimuli (= SC)	0	ST	--	--	--	
	42		-15					
	43	8 sets of 4 stimuli (≠ SC)	0					
	44		-15					
	45	8 sets of 5 stimuli (= SC)	0		--	--	--	
	46		-15					
	47	8 sets of 5 stimuli (≠ SC)	0					
	48		-15					

Note: BN = background noise; C + VM = closure + verbal memory; FG + VM = figure-ground + verbal memory; ISI = inter stimuli interval; ITr. = interhemispheric transfer; NVC = nonverbal closure; NVFG = nonverbal figure-ground; NVS = nonverbal stimuli; SC = semantic category; S/N = signal to noise ratio; ST = Story; TO = temporal ordering; VC = verbal closure; VFG = verbal figure-ground