

Performance of children with reading difficulties after auditory training

Desempenho de crianças com distúrbio de leitura após o treino auditivo

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ABSTRACT

Purpose: To evaluate reading performance and auditory temporal resolution in children with reading difficulties after auditory training.

Methods: Twenty 8 year- old children, 10 with reading difficulties (Study Group) and 10 without reading difficulties (Control Group) were assessed. All subjects participated in an initial assessment and reassessment of auditory temporal resolution (Frequency Pattern, Duration Pattern, and Gap in Noise (GIN) Tests) and reading performance (Clinical Reading Protocol and Phonological Awareness Test - CONFIAS). The Study Group was submitted to eight auditory training sessions. **Results:** The Control Group showed superior performance on all tests compared to the Study Group at both assessment and reassessment. The difference in performance before and after training was statistically significant for almost all tasks in the Study Group, except for phonological awareness. **Conclusion:** The auditory training proved effective for improving performance on auditory temporal and reading tasks in children with reading difficulties.

Keywords: Dyslexia; Auditory perception; Reaction time; Child; Reading

RESUMO

Objetivo: Verificar o desempenho de leitura e da habilidade auditiva de resolução temporal em crianças com dificuldades de leitura, após o treino auditivo. **Métodos:** Participaram deste estudo 20 crianças na faixa etária de 8 anos, sendo dez escolares com dificuldades de leitura (Grupo Estudo), e dez escolares sem dificuldades escolares (Grupo Controle). Todos os indivíduos foram submetidos à avaliação inicial e reavaliação da resolução temporal auditiva (Padrão de Frequência, Padrão de Duração e *Gap in noise* (GIN) e de leitura (Protocolo de Leitura Clínica e Teste de Consciência Fonológica - CONFIAS). O Grupo Estudo foi submetido a oito sessões de treinamento auditivo. **Resultados:** Verificou-se que o Grupo Controle obteve maior desempenho em todos os testes aplicados, quando comparado ao Grupo Estudo, na avaliação inicial e na reavaliação. A diferença do desempenho antes e depois do treinamento auditivo foi significativa para quase todas as tarefas no Grupo Estudo, exceto para a consciência fonológica. **Conclusão:** O treino auditivo foi efetivo para a melhora de desempenho nas habilidades auditivas temporais e de leitura em crianças que apresentam dificuldades de leitura.

Descritores: Dislexia; Percepção auditiva; Tempo de reação; Criança; Leitura

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INTRODUCTION

Auditory temporal resolution is one of the aspects involved in auditory temporal processing⁽¹⁾. Temporal resolution is defined as the ability to detect time gaps between sound stimuli, or identification of the shortest time interval between sound stimuli that an individual can discriminate⁽²⁾.

Although the relationships among deficits in auditory processing, language impairments and learning disabilities are complex, comorbidity is common. More specifically, many children with learning disabilities exhibit temporal processing deficits^(3,4). This association can be explained by the fact that some individuals with auditory temporal processing problems have deficits in the maturation of auditory abilities, leading to learning, reading and speech difficulties⁽⁵⁾.

There is evidence in the literature that children with auditory temporal disorders are more susceptible to language and learning disabilities, suggesting that temporal resolution is fundamental to both speech perception⁽⁶⁾ and normal development of language⁽⁷⁾. The correlation between deficits in auditory abilities and metaphonological skills impairs the mechanism of analysis, synthesis, segmentation and manipulation of sounds and syllables necessary during speech and reading^(8,9).

The perception of sound information to decode and code phonemes is fundamental for acquiring the ability to read. Consequently, children with difficulties in processing sound stimuli of speech may exhibit deficits in segmentation and manipulation of the phonological structure of language which in term leads to reading and writing difficulties^(9,10).

Some studies advocate auditory training of these impaired auditory temporal processing abilities for rehabilitation^(11,12). The main focus of the use of auditory training is to promote plasticity of the central auditory system, since both plasticity and maturation are dependent, in part, on stimulation. With experience, the specific neural pathways are activated while compensatory strategies also become enhanced. Auditory stimulation through auditory training, in combination with other behavioral interventions, can augment synaptic activity, optimizing the neural circuits promoting an increase in the number of neurons and a shift in neural synchrony time, favoring behavioral changes⁽¹³⁾.

When auditory processing disorders and learning difficulties are detected early, there is a greater possibility of providing parents with good orientation, and also of facilitating the conduct of teachers in the learning process and allowing referral of the student for speech pathology and audiology assessment where required^(14,15).

Thus, the objective of this study was to evaluate reading performance and auditory temporal resolution in children with reading difficulties after auditory training.

METHODS

This study was approved by the Research Ethics Committee

(CEP) of the Irmandade da Santa Casa de Misericórdia de São Paulo and by the Faculdade de Ciências Médicas da Santa Casa de São Paulo (FCMSCSP), under protocol 179/09. All subjects took part voluntarily after their legal guardians had received explanation about the study and signed the respective Free and Informed Consent Form (TCLE).

The following study inclusion criteria were adopted: to be a resident in Greater São Paulo; attend a public school; and to have pure-tone and speech audiometry within normal limits for the pediatric population, as established by previous studies⁽¹⁶⁾. Twenty subjects took part in the present study, comprising 11 girls and nine boys, all of whom were 8-year-old, students of a public Primary school in São Paulo city.

The Control Group consisted of ten children with no learning difficulties randomly selected by the teachers, whereas the Study Group included ten children with learning difficulties, including reading difficulties, also randomly selected by the teachers.

The equipment employed for the audiological assessment was: an otoscope, sound-proof booth, audiometer (Itera model by Madsen®), ear phones, lists of tri-syllable and mono-syllable words, and a middle ear analyzer (Octoflex model by Madsen®). The equipment conformed to the following standards: ANSI S3,6-1989; ANSI S3,43-1992; IEC 645-1 (1992); and IEC 645-2 (1993). A CD player (Philips®) coupled to an audiometer (Itera-Madsen®), was used for the auditory processing tests.

All subjects were submitted to the following tests and assessments: a basic audiological evaluation (Pure-tone Audiometry, Speech Audiometry and Immittance screening), three Auditory Processing Tests (Frequency Pattern - Auditec⁽¹⁷⁾, Duration Pattern - Auditec⁽¹⁷⁾ and Gap in Noise - GIN⁽¹⁸⁾), a Reading Abilities Assessment (Reading and Writing Protocol)⁽¹⁹⁾ and the Phonological Awareness Test (CONFIAS)⁽²⁰⁾. All tests were conducted at the Speech Pathology Clinic of the Santa Casa de São Paulo.

The study was divided into three stages: (a) assessment of both groups, performed during two consecutive weeks; (b) auditory training (AT) involving the Study Group only, which received weekly 40-minute sessions over a period of eight weeks; (c) reassessment of both groups after the eight-weeks of AT, during two consecutive weeks.

Auditory training was conducted using a notebook computer (Acer) running the "Auditory temporal training with non-verbal and verbal stimuli with expanded speech®" software program, which contains verbal and non-verbal games, based on the "*Fast Forward Language*" auditory training program⁽²¹⁾. In each training session, 20 minutes were dedicated to the non-verbal game ("Monkey Game") and 20 minutes to the verbal game ("Parrot Game").

The non-verbal game ("Monkey Game") focused on training frequency discrimination and sequencing skills. Symbols were displayed on the screen and had to be matched with the

corresponding sound stimulus. The symbols = or ≠, were used for discrimination of the stimuli; ↑ or ↓, for sequencing, where ↑ represented a rising stimulus, of frequencies in the 500 Hz to 2000 Hz range and ↓ represented a falling stimulus, of frequencies in the 2000 Hz to 500 Hz range (Figures 1 and 2). The verbal game (“Parrot Game”) was used to train phoneme discrimination skills. The auditory stimuli were syllables consisting of an initial consonant, with expanded and amplified production duration. Upon hearing two similar-sounding syllables, the player had to discriminate and order the pair of sounds, matching them to the first syllable of the corresponding cartoon illustration displayed on the screen (Figure 3). Both games incorporated automatic adaptation of variables such as duration of sound stimuli, size of gap between stimuli and production duration of the phonemes, according to player performance. In addition, each player had their own area for accessing the system allowing each session to be personalized, i.e. carrying on from the last phase reached by the player in the previous session.

The following variables were analyzed for each study participant: group (comparison between Study Group and Control Group), Gap-in-Noise detection threshold (GIN), by ear, (initial

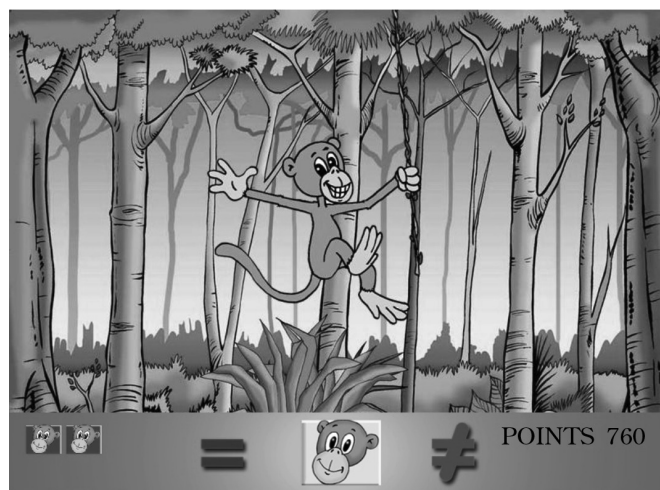


Figure 1. Frequency discrimination

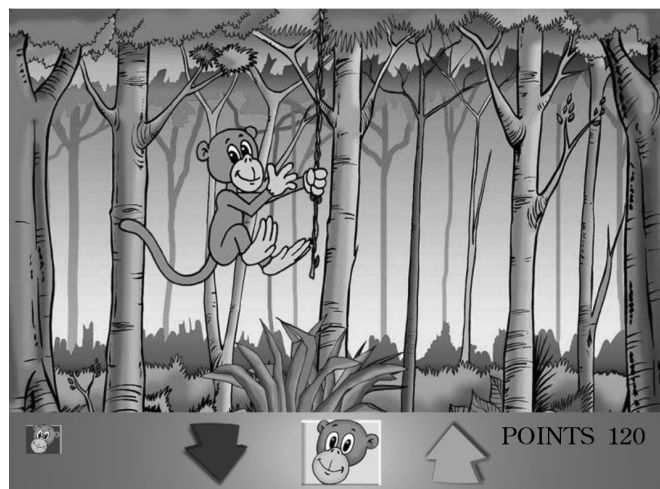


Figure 2. Frequency sequencing



Figure 3. Verbal discrimination and sequencing

assessment and reassessment); percentage correct responses in frequency and duration tests (initial assessment and reassessment); points scored on the reading protocol (initial assessment and reassessment); points scored on phonological awareness test (CONFIAS) (initial assessment and reassessment).

The data were submitted to descriptive and inferential statistical analyses using the following statistical tests: Mann-Whitney test; Confidence Interval for Mean; and repeated-measures Analysis of Variance (ANOVA). The descriptive level was focused in all tests, with a significance level of 0.05 (or 5%) for rejection of the null hypothesis.

RESULTS

A statistically significant difference ($p < 0.05$) in performance of the Study group between assessment and reassessment on the Frequency Pattern and Duration Pattern tests was detected (Table 1).

A statistically significant difference in performance of the Study Group, between assessment and reassessment, on the threshold of the left ear was observed ($p < 0.016$) (Table 2). Comparison of the two groups during assessment and reassessment revealed a statistical difference only for the threshold of the left ear ($p < 0.003$).

On the comparison of Study Group and Control Group for performance at assessment and reassessment on the Word Reading test for words read in one minute and on the Total Time of Word Reading, only Total Time of Reading exhibited a significant difference between the groups ($p < 0.009$) (Table 3).

With regard to the performance at assessment and reassessment of the Study Group versus Control Group on the CONFIAS test, statistically significant differences were observed ($p < 0.006$; $p < 0.001$ and $p < 0.001$) at the Syllable Level, Phoneme Level and Total scores, respectively, on comparison of the total sample for all items of the CONFIAS (Table 4).

DISCUSSION

Based on the results obtained, it was evident that the Control Group had superior performance on the Frequency Pattern

Table 1. Performance on Pitch Pattern and Duration Pattern tests by group at assessment and reassessment phases

Group	Variable	Phase	Mean %	Median %	Standard deviation %	p-value
Control Group	Frequency pattern	Assessment	81.5	82.5	14.0	0.015*
		Reassessment	86.5	87.5	11.1	
	Duration pattern	Assessment	56.9	55.0	12.2	0.035*
		Reassessment	70.0	70.0	13.7	
Study Group	Frequency pattern	Assessment	69.9	72.5	11.9	0.528
		Reassessment	87.0	90.0	7.9	
	Duration pattern	Assessment	30.6	30.0	17.2	0.005*
		Reassessment	73.5	75.0	13.8	

*Significant values ($p < 0.05$) - Wilcoxon's test

Table 2. Performance on Gap-in-Noise (GIN) test by group and ear at assessment and reassessment phases

Group	Ear	Phase	Mean (ms)	Median (ms)	Standard deviation (ms)	p-value
Control Group	Right	Assessment	5.1	5.5	1.1	0.851
		Reassessment	5.0	5.0	0.7	
	Left	Assessment	4.8	4.5	0.9	0.059
		Reassessment	4.3	4.0	0.7	
Study Group	Right	Assessment	6.9	6.0	2.2	0.093
		Reassessment	5.4	5.5	0.7	
	Left	Assessment	6.8	7.0	1.9	0.016*
		Reassessment	5.1	5.0	0.6	

*Significant values ($p < 0.05$) - Wilcoxon's test

Table 3. Performance on word and pseudoword reading tests by group at assessment and reassessment phases

Group	Variable	Phase	Mean	Median	Standard deviation	p-value
Control Group	Reading Protocol – words read in 1 min.	Assessment	54.8	58.5	13.5	0.540
		Reassessment	56.1	63.0	16.1	
	Reading Protocol – total time	Assessment	01:35	01:29	00:33	0.219
		Reassessment	01:22	01:09	00:33	
Study Group	Reading Protocol – words read in 1 min.	Assessment	26.5	26.5	14.3	0.046*
		Reassessment	35.0	36.0	13.9	
	Reading Protocol – total time	Assessment	04:02	02:43	02:58	0.016*
		Reassessment	03:06	02:23	01:45	

*Significant values ($p < 0.05$) - Wilcoxon's test

and Duration Pattern test compared to the Study Group. One explanation for these findings is that to perform well on these tests the child must have normal auditory temporal sequencing and inter-hemispheric transfer abilities⁽²²⁾.

Some studies drawing on qualitative data collected at the time of application of the auditory processing tests have shown difficulties among individuals with impaired auditory processing in understanding the instructions to perform each test, typical of Central Auditory Processing Disorder (CAPD). This raises two questions: (i) it is unclear whether the differentiated results of the Study Group can be attributed to difficulties in

understanding the instructions given or to performing the skill itself; and (ii) whether a high level of attention was required on each task, given that the auditory stimuli were delivered at a fast rate⁽²³⁾.

A previous study, which sought to determine the auditory learning characteristics in 86 typically developing children using various different modalities of auditory and linguistic stimuli⁽²⁴⁾, found that improvements after auditory training in the Control Group were attributable to the test-retest effect, rendering it impossible to determine the extent to which the post-training improvement in the study group had stemmed

Table 4. Performance on Phonological Awareness test (CONFIAS) by group at assessment and reassessment phases

Group	Variable	Phase	Mean	Median	Standard deviation	p-value
Control Group	CONFIAS Syllable	Assessment	36.5	37.0	2.9	0.159
		Reassessment	37.6	39.0	3.9	
	CONFIAS Phoneme	Assessment	21.6	22.5	4.3	0.008*
		Reassessment	26.2	26.0	1.8	
	CONFIAS Total	Assessment	58.1	57.0	5.8	0.022*
		Reassessment	63.8	65.5	4.6	
Study Group	CONFIAS Syllable	Assessment	33.4	35.5	5.5	0.017*
		Reassessment	35.8	38.0	5.4	
	CONFIAS Phoneme	Assessment	15.0	17.0	7.1	0.007*
		Reassessment	21.1	22.0	4.6	
	CONFIAS Total	Assessment	48.4	52.0	12.1	0.007*
		Reassessment	56.9	60.0	9.3	

*Significant values ($p < 0.05$) - Wilcoxon's test

exclusively from the training or from the effect of repeating the same test.

The results of the Gap-in-Noise (GIN) test for both groups showed that thresholds in left and right ears were greater in the Control Group than in the Study Group. Furthermore, no significant difference between ears was found. These results corroborate the findings of other studies^(25,26). The GIN test assesses temporal resolution^(26,27) where some studies employing this test to assess the gap detection threshold in individuals with normal hearing have reported values ranging from 3.98 to 6.07 ms⁽²⁸⁾. These threshold values were consistent with those found in the Control Group of the present study (6 ms).

Some studies⁽²⁷⁻²⁹⁾ have sought to associate speech and writing impairments with temporal resolution deficits. The results of these studies showed that individuals with phonological deficits and dyslexia can exhibit auditory temporal processing deficit and that more time is required to detect the gaps between sound stimuli⁽²⁹⁾. The findings of the present study are in agreement with reports in the literature, since the group of reading-impaired children had greater gap thresholds in both ears than the group of children without auditory processing or reading impairments.

The poor performance attained by the Study Group on the auditory temporal processing tests may point to a possible relationship between reading and temporal auditory processing, in line with a number of studies in the literature^(29,30). Concerning the worse performance of dyslexic children on auditory temporal processing tests, some authors have pointed out that other factors may affect phonological performance such as cognitive skills, particularly attentional ability and working memory⁽³⁰⁾. All these skills are essential to learning, especially in situations involving reading. The neural networks were stimulated by the training and may have improved attention and memory as well as perception of speech, thereby enhancing reading accuracy.

Another noteworthy question centers on whether the performance improvement seen in the Study Group after auditory

training was attributable to the test-retest effect. Further studies investigating this possibility in a larger sample are needed. In addition, the inclusion of assessments using electrophysiological tests may attenuate some of the effects present in the behavioral tests. Future studies should include a group of individuals with the same characteristics as the other test subjects, submitted to a passive auditory stimulation in order to better assess the true benefits of an active auditory stimulation for enhancing reading performance post intervention.

CONCLUSION

The auditory training proved effective for improving performance on auditory temporal and reading tasks in children with learning difficulties.

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