Original Article

https://doi.org/10.1590/2317-6431-2018-2016

Audiology Communication Research
ISSN 2317-6431

Performance of school-aged children in the basic audiological evaluation and the binaural integration task

Desempenho de escolares na avaliação audiológica básica e na tarefa de integração binaural

Nádia Giulian de Carvalho[1], Carolina Verônica Lino Novelli[1], Maria Francisca Colella-Santos[2]

ABSTRACT

Purpose: To analyze the auditory performance of students in basic audiological evaluation, and later, in cases of integrity of the peripheral auditory pathways, to evaluate and compare the performance of children with good school performance (GC) and unsatisfactory school performance (GE) in binaural integration task. **Methods:** Cross-sectional and descriptive study. Anamnesis, basic audiological evaluation, and Dichotic Digits Test (DDT) were performed. The sample consisted initially of 63 children in the GE and 61 in the GC. The inclusion criteria for basic audiological evaluation for both groups were: schoolchildren aged from 8 to 10 years, native speakers of Brazilian Portuguese, with adequate understanding of the instructions provided. **Results:** The groups were homogeneous regarding age and heterogeneous regarding gender, with more boys in GE and girls in GC. Children of the GE presented worse hearing behavior in noisy environment, attention and agitation, in the perception of guardians. In the peripheral auditory evaluation, there was a statistically significant difference between the groups. GE presented hearing loss and/or alteration of the middle ear in a larger number of children. In DDT, statistically significant differences were found between the groups, the GE presented worse performance in the task of binaural integration. **Conclusion:** Children with unsatisfactory school performance presented worse peripheral auditory performance and figure-background ability for verbal sounds. Thus, auditory screening programs should include procedures of the basic audiological evaluation and the central auditory processing.

Keywords: Hearing; Hearing Tests; Students; Auditory Perception; Child

RESUMO

Objetivo: Analisar o desempenho auditivo de escolares na avaliação audiológica básica e, posteriormente, nos casos de integridade das vias auditivas periféricas, avaliar e comparar o desempenho de crianças com bom desempenho escolar (GC) e desempenho escolar insatisfatório (GE), na habilidade auditiva de integração binaural. **Métodos:** Estudo do tipo transversal e descritivo. Foram realizadas anamnese, avaliação audiológica básica e teste dicótico de dígitos (TDD). A amostra foi composta, inicialmente, por 63 crianças no GE e 61 no GC. Os critérios de inclusão para avaliação audiológica básica para ambos os grupos, foram: escolares na faixa etária de 8 a 10 anos, falantes nativos do Português Brasileiro, com compreensão adequada às instruções fornecidas. **Resultados:** Os grupos foram homogêneos quanto à faixa etária e heterogêneos em relação ao gênero, com mais meninos no GE e meninas no GC. As informações da anamnese revelaram que as crianças do GE apresentaram pior comportamento auditivo de escuta em ambiente ruidoso, atenção e agitação, na percepção dos responsáveis. Na avaliação auditiva periférica, houve diferença estatisticamente significativa entre os grupos, sendo que o GE apresentou perda auditiva e/ou alteração de orelha média em um número maior de crianças. No TDD, foram encontradas diferenças estatisticamente significativas entre os grupos, demonstrando que escolares com rendimento escolar insatisfatório tiveram pior desempenho na tarefa de integração binaural. **Conclusão:** Crianças com rendimento escolar insatisfatório apresentaram pior desempenho auditivo periférico e na habilidade de figura-fundo para sons verbais. Desta forma, programas de saúde auditiva devem incluir procedimentos da avaliação audiológica básica e do processamento auditivo central.

Palavras-chave: Audição; Testes Auditivos; Escolares; Percepção Auditiva; Crianças

Work carried out in the Laboratório de Audiologia do Departamento de Desenvolvimento Humano e Reabilitação – DDHR, Faculdade de Ciências Médicas da Universidade Estadual de Campinas – UNICAMP – Campinas – (SP), Brasil.

[1]Programa de Pós-graduação (Doutorado), Centro de Investigação em Pediatria – CIPED, Faculdade de Ciências Médicas – FCM, Universidade Estadual de Campinas – UNICAMP – Campinas (SP), Brasil.

[2]Departamento de Desenvolvimento Humano e Reabilitação, Centro de Investigação em Pediatria – CIPED, Faculdade de Ciências Médicas – FCM, Universidade Estadual de Campinas – UNICAMP – Campinas (SP), Brasil.

Conflict of interest: No.

Authors' contribution: NGC: researcher who designed the study, participated in all steps, study concept and design, data collection, analysis, and interpretation, and in the writing of the article; CLN: contributed to data collection, writing and revision of the article, and final approval of the version to be published; MFCS: guided all the study process, participated in a intellectually meaningful way of the processes of data analysis and interpretation, writing and revision of the article.

Corresponding author: Nádia Giulian de Carvalho. E-mail: nadiagiulian@gmail.com

Received: May 16, 2018; **Accepted:** September 12, 2018

INTRODUCTION

The concern with auditory aspects of school children has increased, due to the high incidence of peripheral auditory changes in this population[1,2]. At the time of school socialization, between the ages of 4 and 7 years, there is a high incidence of middle ear disorders, such as otitis, related to imbalance of protection mechanisms, aeration, and drainage of the middle ear[3]. Therefore, students should be evaluated and followed up systematically. The auditory peripheral changes may compromise the central auditory pathways, with subsequent loss in auditory skills. Changes in auditory skills may be related to difficulties in oral and written language[4-7].

The literature has discussed about which tests may be sensitive and complementary for the screening of children, beyond the peripheral auditory system. The Dichotic Digits Test (DDT) has been referred to as a potential test[8], due to the significant correlation of school performance with dichotic processing, binaural integration mechanism, and figure-background ability[9]. The dichotic tests are the most sensitive ones to assess the figure-background ability to verbal sounds, as they analyze the cortical structures involved and, in addition, can be applied with children aged from 5 years[10], thus allowing school use in the early years and guiding appropriate conducts from the results obtained. We highlight the importance of the figure-background ability on communicative environments that involve the task of directing the attention to the chosen stimulus, in competition with others, such as the classroom environment, where it is necessary to direct the attention to the teacher's explanation and understand the communication even when it is noisy. Based on previous studies[8,9], two hypotheses are suggested: 1. The performance in peripheral hearing evaluations and in the ability of figure-background will be worse in children with unsatisfactory school performance; 2. The Dichotic Digits Test can be a potential test for screening and differentiating the figure-background ability of schoolchildren.

The objective of this study was to analyze the auditory performance of students in a basic audiological evaluation, and later, in cases of integrity of the peripheral auditory pathways, to evaluate and compare the performance of children with good school performance (GC) and unsatisfactory school performance (GE) in binaural integration task, considering variations of age, gender, and ear side.

METHODS

This is a study of cross-sectional and descriptive design. It was approved by the Research Ethics Committee – FCM/Unicamp, opinion 687.690 of 2014.

The sample was composed by children enrolled in five municipal public schools. Each pedagogical team selected in its school unit 15 students aged between 8 and 10 years, who presented good school performance, i.e., who got the best grades in the subjects. The team also selected 15 children with unsatisfactory school performance. The term "unsatisfactory school performance" was used to refer to all children selected by the pedagogical team, whose performance was not compatible with the cognitive ability and surpassed the difficulties faced by their classmates. After the selection, the researchers contacted the guardians by phone to extend the invitation. One hundred and fifty families were contacted and, of these, 124 agreed to accompany the children in place of hearing evaluations.

For initial analysis of school performance in basic audiological evaluation, the individuals were divided into two groups: study group (GE), composed by 63 children with unsatisfactory school performance; and the control group (GC), composed by 61 children with satisfactory school performance. The inclusion criteria, for both groups, in this stage were: schoolchildren aged from 8 to 10 years, native speakers of Brazilian Portuguese, with adequate understanding of the instructions provided. The legal guardians signed the informed consent form.

Exclusion criteria specific to each group were:

GE: Children with medical diagnosis of cognitive changes/syndromes; presence of earwax plug, at the time of the evaluation.

GC: Children with medical diagnosis of cognitive changes/syndromes; speech, hearing, and school complaints; presence of earwax plug, at the time of the evaluation.

The adopted procedure followed the following steps: anamnesis with the parents or legal guardians, through a questionnaire for sample characterization as to age, gender, social behaviors (quiet, agitated, and distracted), auditory behaviors (hearing complaints, sound localization, episodes of otitis, and situation of hearing in noisy environments), and basic audiological evaluation (audiometry with airway and bone pathway research and, when necessary, logoaudiometry and immitanciometry).

The following hearing values were considered within the standards of normality: 1. tonal audiometry from 250 to 8000 Hz: tonal thresholds means by airway (AW) from 500 to 4000 Hz up to 15 dB[11]; 2. logoaudiometry: speech recognition threshold and speech recognition index compatible with the findings of the tonal audiometry[12]; 3. immitanciometry: type A tympanometric curve, bilaterally, and presence of ipsilateral and contralateral acoustic reflexes, on all frequencies (500, 1,000, 2,000, 3,000, and 4000 Hz)[13].

Only the students who presented basic audiological evaluation within the standards of normality, as described, proceeded to the second stage of the study: evaluation of the binaural integration task through the application of DDT. In this step of the analysis, the sample was composed by 43 schoolchildren in GE and 54 in the GC.

The DDT consists of a list of 80 digits, representing dissyllables of the Portuguese language, grouped in two pairs. The intensity of presentation of the stimulus was 50 dBNS, regarding the mean of the hearing thresholds in the frequencies of 500, 1,000, and 2,000 Hz, obtained in the tonal audiometry. The test was applied to the condition of binaural integration, in which the individual is guided to repeat the four digits heard, in a sequence of 20 presentations started in the right ear and subsequently in the left ear, totaling 160 digits[14]. The performance of the schoolchildren was classified as normal or altered, as the criteria of normality, according to which, at 8 years old, a response of correct answers from the RE greater than or equal to 85% is expected, as well as, considering the LE, greater than or equal to 82%. As for the ages of 9 and 10 years, a percentage of at least 95% of correct answers is expected[15].

Basic audiological evaluation tests and, subsequently, DDT, were applied in an acoustic booth by audiometer AC40, TDH39 earphones, and immitate meter 235H, both from the Interacoustics brand, properly calibrated. The legal guardians and the participating schools received feedback from which children presented, in the first analysis, peripheral changes of hearing and, in the second analysis, performance below the normal range regarding the figure-background ability, as well as referrals to medical evaluation and complementary examinations.

The means of hearing thresholds of the frequencies of 500, 1,000, and 2,000 Hz were calculated for subsequent statistical comparison of the tonal auditory threshold between the groups. To describe the sample profile, according to the variables of the study, the descriptive statistics were calculated, with mean values, standard deviation, as well as minimum, maximum and median values. ANOVA, Chi-square, Mann-Whitney, and two portions equality tests were used. The significance level adopted for the study was 5% ($p < 0.05$), highlighted in bold in the tables.

RESULTS

The data on the characteristics of the 124 children, regarding gender, demonstrated statistically significant difference between the groups. In the GC, 28 children were male and 33 were female. In GE, 43 children were male and 20 were female ($p=0.027$). Regarding age, the groups were homogeneous ($p=0.75$). GC was constituted by 25 children aged 8 years, 19 children aged 9, and 17 children aged 10. In GE, there were 25 children aged 8 years, 19 aged 9, and 19 aged 10.

From the anamnesis data, we verified behavioral differences ($p<0.005$) between the groups, such as inattention, agitation, and difficulty to hear in noisy environments. As no statistically significant differences were found between the ears, in the results of the basic audiological evaluation, the comparison between the groups was carried out joining the right and left ears.

Statistically significant difference was observed for the mean results of tonal thresholds (TT) by AW and speech recognition thresholds (SRT), between the groups. As for TT, the GC presented a mean of 8.02; while GE presented a mean of 11.91 (p-value GC × GE = 0.0024). As for SRT, the GC presented a mean of 11.06; while GE presented a mean of 15.12 (p-value GC × GE = 0.0009). These differences can be attributed to the higher incidence of hearing loss in the GE, which consequently influenced the TT and SRT means. Regarding speech recognition index (SRI), GC presented a mean of 98.85, while GE presented a value of 98.18 (p-value = 0.0728), thus demonstrating that there is no difference in this test. The statistical test used was ANOVA.

In the joint analysis of the tests, hearing was classified as exclusive change of the middle ear and/or hearing loss. We verified hearing loss of the conductive type in 3 children of the GE, with 1 case of light bilateral commitment. The second case presented light bilateral hearing loss and the third, light unilateral commitment in the left ear. The other types of losses found in GE were 1 light sensorioneural loss, on the right ear, and severe in the left ear and 1 light mixed type loss, bilaterally. In GC occurred 1 case of moderately severe conductive hearing loss and 1 case of light sensorioneural hearing loss, both being unilateral commitment of the left ear. The two children were refreed to monitoring and medical conduct with an otolaryngologist and did not performed the DDT evaluation.

In the joint analysis of the peripheral auditory evaluation, statistically significant differences were found between the groups in the classification of normal hearing (p-value = 0.0048) and, consequently, higher incidence of change of middle ear and/or hearing loss in GE (p-0.0083 = value), as shown in Table 1.

Given the exclusion of children with peripheral auditory changes, we forwarded to the DDT evaluation 97 schoolchildren who presented normal peripheral hearing, divided into GC, with 54 individuals, and GE, with 43. Initially, we compared the ears within the group. In GC, the performance of the right ear was 96.55 ± 3.68 and, of the left ear, 95.46 ± 4.36. In GE, on the other hand, the performance of the right ear was 83.31 ± 11.58 and, of the left ear, 80.78 ± 11.35. There was statistically significant difference in performance between the right and left ears, with better performance of the right ear in both groups (GC: p-value = 0.021 and GE: p-value = 0.050). Therefore, the remaining analyses compared by side of the ear.

There was statistically significant difference in the performance of DDT within each groups, considering the age group. Performance at the test improved as the age increased (Table 2).

In the comparison of groups (GC × GE), considering the performance by ear, we found statistically significant differences. Children with unsatisfactory school performance presented worse performance in the binaural integration task (Table 3).

In the GC, 100% of the children presented normal results in DDT, for both right and left ears. In GE, 30.2% of children presented results within the standards of normality, while considering the left ear, normal results were obtained in 25.6% of children (Table 4).

DISCUSSION

The concern with the peripheral and central auditory system should be part of routine health care, especially when the target public is children. This stage of life is crucial to the acquisition and development of oral and written language, since the hearing integrity is essential to learning. Thus, this study was dedicated to the application of procedures that could allow peripheral auditory evaluation and a mechanism of central

Table 1. Children from the study group and control group, considering the comparison of groups in the results of the peripheral auditory evaluation: normal hearing and change of the middle ear and/or hearing loss

GROUP	n	Classification	n (%)	p-value (GE × GC)
GC	61	Normal hearing	55 (90.16%)	0.0048
GE	63	Normal hearing	44 (69.84%)	
GC	61	Change of the middle ear and/or hearing loss	6 (9.84%)	0.0083
GE	63	Change of the middle ear and/or hearing loss	18 (28.57%)	

Chi-square test

Subtitle: GE = study group; GC = control group; N = number of individuals

Table 2. Performance of children from the study group and control group in the Dichotic Digits Test, considering the age variable within each group

GROUP	AGE	N	DDT	MEAN (%)	p-value (8 × 9 × 10)
GC	8	20	RE	93.50	<0.001
GC	9	18	RE	98.06	
GC	10	16	RE	98.67	
GC	8	20	LE	91.31	<0.001
GC	9	18	LE	97.57	
GC	10	16	LE	98.28	
GE	8	16	RE	79.45	0.010
GE	9	13	RE	80.00	
GE	10	14	RE	90.80	
GE	8	16	LE	77.50	0.034
GE	9	13	LE	77.98	
GE	10	14	LE	87.14	

ANOVA Test; GC: 8< 9 and 10 years; 9=10 years, GE: 8< 10 years; 8 =9 years; 9- 10 years

Subtitle: GE = study group; GC = control group; DDT = Dichotic Digits Test; LE = left ear; RE = right ear; N = number of individuals

Table 3. Performance of children from the study group and control group in the Dichotic Digits Test, considering the right and left ears

Digits (%)	Right Ear		Left Ear	
	GC (N=54)	GE (N=43)	GC(N=54)	GE(N=43)
Mean	96.55	83.31	95.46	80.78
Median	97.50	86.25	96.25	82.50
Standard deviation	3.68	11.58	4.36	11.35
Minimum	85.00	57.50	83.75	42.50
Maximum	100.00	100.00	100.00	98.75
Confidence interval	0.98	3.46	1.16	3.39
P-value	<0.001		<0.001	

ANOVA Test

Subtitle: GE = study group; GC = control group; N = number of individuals

Table 4. Performance of children from the study group and control group in the Dichotic Digits Test, considering the side of the ear within each group and between groups

	GC		GE	
	RE	LE	RE	LE
	N %	N %	N %	N %
Changed	0 0%	0 0%	30 69.8%	32 74.4%
Normal	54 100%	54 100%	13 30.2%	11 25.6%
p-value (RE × LE)	1.000		0.631	
p-value (GC × GE)	0.0001		0.0001	

Two Portions Equality Test

Subtitle: GE = study group; GC = control group; LE = left ear; RE = right ear; N = number of individuals

auditory processing, highlighting the importance of DDT in the evaluation of binaural integration task and figure-background ability to verbal sounds.

We found that the variable gender showed difference when comparing the groups, i.e., boys presented unsatisfactory school performance when compared to girls. The literature has already described this panorama and identified a greater number of male children obtaining negative school grades[16], in addition to more referrals for multidisciplinary and hearing evaluations[17,18]. The influence of gender in school performance is not entirely clear and some studies suggested behavioral differences related to time devoted to reading, between boys and girls[19]. Another study pointed out that some girls are not easily identified and, thus, further studies are needed to clarify the impact of gender on learning[20].

Homogeneous distribution regarding age group allowed an equal comparison between the groups, concerning the studied aspects. The age of 8 years proved to be a transitional and maturation phase for auditory skills involving binaural integration, with better performance from children aged 10 years (Table 2). Still regarding the characterization of groups, we observed in the anamnesis data on social and auditory behavior, that the families of children with unsatisfactory school performance (GE) shared more complaints related to behaviors of inattention and agitation of the children, as well as difficulties of hearing in noisy environments. There were statistically significant differences in these behaviors, when compared to the GC. Inattention is one of the typical recurring complaints on the speeches of family members of children who received the diagnosis of central auditory processing disorder, wit the following terms being often used: “is often distracted”, “with the had in the clouds”, “he only listens when he wants to”, “do not pay any attention to the teacher”, and “is unable to learn”[10]. In addition to inattention, behaviors of agitation and not hearing well in noisy environment are characteristics that must be taken as alerts for professionals, families, and school, as they suggest need for evaluation of auditory skills, as well as an interdisciplinary evaluation, since they can coexist in more than one clinical picture. We did not perform a formal cognitive assessment of children, being this a limitation of this study, given relevant recent discussions about the nature of the central auditory processing disorder (CAPD) and the direct relationship (or not) with higher cognitive functions, such as attention, memory, and language[21]. To minimize this limitation, the pedagogical team was careful in the selection of students, particularly of those with unsatisfactory school performance, and the speech therapist ensured a careful examination, considering the child’s behavior during the evaluation (language, attention, memory, and motivation). A previous study found a correlation between performance on cognitive tests of sustained auditory and visual attention, as well as non-verbal intelligence with DDT. However, the authors stressed that the variable inattention and poor performance in DDT, although occurring concomitantly in some children, are conditions considered widely independent, i.e., although inattention may contribute to the poor performance in auditory tasks, it does not determine the performance in the test[22].

The results showed statistically significant difference in the basic audiological evaluation and high incidence of changes of middle ear and hearing deviant from normality, in the children from the GE, with higher incidence of hearing loss of the conductive type (Table 1). The findings of the peripheral auditory evaluation are consistent with the literature, noting a high incidence of hearing loss of the conductive type schoolchildren[18,23]. Conductive loss must be identified and treated as early as possible, since hearing degradation can impair school performance, due to the loss of details that a sound information can possess[24]. The identification of hearing changes and appropriate interventions are necessary to facilitate the learning process. It is a consensus that the effects of hearing sensory deprivation are reflected in the global development of a child, sharply compromising the educational context[24].

Students with hearing within the standards of normality, but with unsatisfactory school performance, presented in this study worse performance in the figure-background ability, evaluated with the application of DDT, in relation to the group with satisfactory school performance, which presented 100% of normalcy (Table 4). The comorbidities of the central auditory processing (CAP), language, and reading disorders were evaluated in 68 schoolchildren. The authors found that about half of the children (47%) had problems in all three areas, suggesting the co-occurrence of language skills with tests of CAP, including DDT, which was the focus of this study[25]. The high incidence of altered results in DDT, in both ears, in GE, suggests evidence of changes in the left hemisphere. Kimura (1961) showed, in his pioneering studies on the application of DDT to individuals with temporal lobe injury and who had undergone unilateral surgery, worst performance of the left temporal lobe, compared to the right temporal lobe, noting that the left temporal lobe is particularly important in the auditory perception of verbal sounds[26].

In addition to the group factor, the right ear had better performance in DDT in both groups (Table 3), a result that agrees with other studies which attested to the better performance of the right ear regarding dichotic hearing, for this age group[8,27,28].

The age group demonstrated influence in the performance in DDT. The children of the GC, aged 8 years, presented worse performance than the children aged 9 and 10 years. In GE, the maturation process occurred later, i.e., children aged 8 years had similar performance to that of children aged 9 years. We observed difference only at 10 years old. Improved test performance is expected for children aged 9 years, in comparison to children aged 8, according to reference criteria[15], which demonstrates that there was a delay in the children from the GE.

The DDT can be considered one of the most widely used tests in research on factors associated with central auditory processing, since it has been applied in at least 50% of the national studies analyzed, as demonstrated by a recent systematic review[29]. Probably this is due to its quick implementation, easiness, scope of age, and evaluation of cortical auditory skills which act as facilitators in the learning process. Furthermore, the usefulness of DDT has been confirmed in the literature, which suggests that the test should be included in hearing screening programs for schoolchildren[8].

Auditory health programs should include procedures of basic audiological evaluation and central auditory processing. The hearing screening of schoolchildren must, therefore, in addition to contemplate peripheral screening procedures, due to its importance in the early identification of peripheral auditory changes, include a screening of the central auditory processing, since the peripheral evaluation alone is not enough to screen children who present difficulties in processing auditory information, which can be reflected in their school abilities. Clinical and educational looks should be extended, regarding the hearing screening of children. In addition, DDT has proved to be a potential test to be inserted in the screening procedure. Referrals can be made for diagnosis of central auditory processing, in addition to the establishment of prevention, promotion, and rehabilitation strategies developed in school and clinical environments, with a focus on the child's global development. In addition, some tasks aimed to stimulate the figure-background ability could be inserted into school activities, with the goal of favoring the decoding of linguistic stimuli, with acoustic competitions in the environment. Some activities that could be developed are: discrimination of phonemes, syllables, words and phrases, and also storytelling with competition of verbal (songs) and non-verbal (competitive noises) stimuli. After the implementation of these strategies of stimulation, it is important to ensure that the learning environment is acoustically favorable, without competitive noises, especially in times when the teacher is transmitting new content, who can also ask questions after the transmitted message, ensuring proper understanding by students.

We suggest that new studies are carried out with schoolchildren, using different tests that evaluate other auditory processing skills so that, together with the Dichotic Digits Test, they may compose a series to properly screen children at risk for central auditory processing disorder. All children with school delay must be examined, in search of diagnosis for changes of central auditory processing disorders, among others.

CONCLUSION

Children with unsatisfactory school performance showed worse peripheral auditory performance and figure-background ability to verbal sounds. The Dichotic Digits Test was effective to identify change in hearing ability of figure-background and in differentiation of the performance of children, according to the school performance.

ACKNOWLEDGEMENTS

The authors thank Espaço da Escrita – Pró-Reitoria de Pesquisa – UNICAMP – for the language services provided.

REFERENCES

1. Dadalto EV, Nielsen CSCB, Oliveira EAM, Taborda A. Prevalence of communication disorders in scholars of the municipal elementary school network of Vila Velha/ES. Rev CEFAC. 2012;14(6):1115-21. http://dx.doi.org/10.1590/S1516-18462012005000024.

2. Lindau TA, Delecrode CR, Cardoso ACV. Achados timpanométricos em um grupo de escolares. Rev CEFAC. 2013;15(6):1453-60. http://dx.doi.org/10.1590/S1516-18462013005000036.

3. Almeida CIR, Almeida RR. Otite media aguda. In: Campos CAH, Costa HOO, editores. Tratado de otorrinolaringologia. São Paulo, SP: Roca, 2003. p. 15-32.

4. Abdo AGR, Murphy CFB, Schochat E. Habilidades auditivas em crianças com dislexia e transtorno do déficit de atenção e hiperatividade. Pro Fono. 2010;22(1):25-30. http://dx.doi.org/10.1590/S0104-56872010000100006. PMid:20339804.

5. Wiemes GRM, Kozlowski L, Mocellin M, Hamerschmidt R, Schuch LH. Cognitive evoked potentials and central auditory processing in children with reading and writing disorders. Braz J Otorhinolaryngol. 2012;78(3):91-7. http://dx.doi.org/10.1590/S1808-86942012000300016. PMid:22714853.

6. Murphy CFB, Schochat E. Correlações entre leitura, consciência fonológica e processamento temporal auditivo. Pro Fono. 2009;21(1):13-8. http://dx.doi.org/10.1590/S0104-56872009000100003. PMid:19360253.

7. Oliveira JC, Murphy CFB, Schochat E. Processamento auditivo (central) em crianças com dislexia: avaliação comportamental e eletrofisiológica. CoDAS. 2013;25(1):39-44. http://dx.doi.org/10.1590/S2317-17822013000100008. PMid:24408169.

8. Skarzynski PH, Wlodarczyk AW, Kochanek K, Pilka A, Jedrzejczak WW, Olszewski L, Bruski L, Niedzielski A, Skarzynski H. Central auditory processing disorder (CAPD) tests in a school-age hearing screening programme – analysis of 76,429 children. Ann Agric Environ Med. 2015;22(1):90-5. http://dx.doi.org/10.5604/12321966.1141375. PMid:25780835.

9. Weihing J, Atcherson SR. Dichotic listening tests. In: Musiek FE, Chermak GD, editors. Handbook of central auditory processing disorder. San Diego: Plural Publishing, 2014. p. 369-404.

10. Pereira LD. Introdução ao processamento auditivo central. In: Bevilacqua MC, Martinez MAN, Balen SA, Pupo AC, Reis ACMB, Frota S, editores. Tratado de audiologia. São Paulo: Santos; 2012. p. 279-91.

11. Northern J, Downs MP. Avaliação auditiva comportamental. In: Northern J, Downs MP, organizadores. Audição na infância. Rio de Janeiro: Guanabara Koogan; 2005. p. 129-67.

12. Frota S, Sampaio F. Logoaudiometria. In: Frota S, editor. Fundamentos em fonoaudiologia. Rio de Janeiro: Guanabara Koogan; 1998. p. 61-8.

13. Carvallo RMM. Timpanometria. In: Bevilacqua MC, Martinez MAN, Balen SA, Pupo AC, Reis ACM, Frota S, editores. Tratado de audiologia. São Paulo: Santos; 2012. p. 123-33.

14. Colella-Santos MF. Processamento auditivo central: teste dicótico de dígitos em indivíduos normais [dissertação]. São Paulo: Universidade Federal de São Paulo; 1998.

15. Pereira LD, Schochat E. Testes auditivos comportamentais para avaliação do processamento auditivo central. 2. ed. Barueri: Pro Fono; 2015. 82 p

16. Carvalho MP. Quem são os meninos que fracassam na escola? CadPesq. 2004;34(121):11-40.

17. Lima RF, Mello RJL, Massoni I, Ciasca SM. Learning disabilities: school-related complaints and diagnoses in a Service of Child Neurology. Rev Neurocienc. 2006;14:185-90.

18. Nogueira JCR, Mendonça MC. Avaliação auditiva em uma população de estudantes da rede pública municipal. Rev Bras Otorrinolaringol (Engl Ed). 2011;77(6):716-20.

19. OECD: Organisation for Economic Co-operation and Development . The ABC of gender equality in education: aptitude, behaviour, confidence, PISA. OECD Publishing; 2015.

20. Cortiella C, Horowitz SH. The state of learning disabilities: facts, trends and emerging issues. New York: National Center for Learning Disabilities; 2014.

21. Ahmmed AU, Ahmmed AA, Bath JR, Ferguson MA, Plack CJ, Moore DR. Assessment of children with suspected auditory processing disorder: a factor analysis study. Ear Hear. 2014;35(3):295-305. http://dx.doi.org/10.1097/01.aud.0000441034.02052.0a. PMid:24496289.

22. Gyldenkærne P, Dillon H, Sharma M, Purdy S. Attend to this: the relationship between auditory processing disorders and attention deficits. J Am Acad Audiol. 2014;25(7):676-87. http://dx.doi.org/10.3766/jaaa.25.7.6. PMid:25365370.

23. Araújo SA, Moura JR, Camargo LA, Alves W. Avaliação auditiva em escolares. Rev Bras Otorrinolaringol. 2002;68(2):263-6. http://dx.doi.org/10.1590/S0034-72992002000200017.

24. Colella-Santos MF, Bragato GR, Martins PMF, Dias AB. Triagem auditiva em escolares de 5 a 10 anos. Rev CEFAC. 2009;11(4):644-53. http://dx.doi.org/10.1590/S1516-18462009000800013.

25. Sharma M, Purdy SC, Kelly AS. Comorbidity of auditory processing, language, and reading disorders. J Speech Lang Hear Res. 2009;52(3):706-22. http://dx.doi.org/10.1044/1092-4388(2008/07-0226). PMid:19064904.

26. Kimura D. Some effects of temporal-lobe damage on auditory perception. Can J Psychol. 1961;15(3):156-65. http://dx.doi.org/10.1037/h0083218. PMid:13756014.

27. Kraft RH. The relationship between right-handed children's assessed and familial handedness and lateral specialization. Neuropsychologia. 1981;19(5):696-705. http://dx.doi.org/10.1016/0028-3932(81)90007-5. PMid:7312154.

28. Musiek FE, Geurkink NA, Kietel SA. Test battery assessment of auditory perceptual dysfunction in children. Laryngoscope. 1982;92(3):251-7. http://dx.doi.org/10.1288/00005537-198203000-00006. PMid:7070168.

29. Carvalho NG, Novelli CVL, Colella-Santos MF. Fatores na infância e adolescência que podem influenciar o processamento auditivo: revisão sistemática. Rev CEFAC. 2015;17(5):1590-603. http://dx.doi.org/10.1590/1982-0216201517519014