Acta Otorrinolaringol Esp. 2009;**60(6):**415-421

Acta Otorrinolaringológica Española

www.elsevier.es/otorrino

ORIGINAL ARTICLE

Assessment of central auditory processes in evaluated in Spanish in children with dyslexia and controls. Binaural Fusion Test and Filtered Word Test

Yolanda Rebeca Peñaloza-López,[a,*] María del Rosario Olivares García,[a] Sabino Jiménez de la Sancha,[a] Felipe García-Pedroza,[b] and Santiago J. Perez Ruiz[c]

[a]*Investigación-Neurofisiología, Comunicación Humana, Instituto Nacional de Rehabilitación, Arenal de Guadalupe, México, D.F. Mexico*
[b]*Medicina Familiar, Facultad de Medicina, Universidad Nacional Autónoma de México, Mexico*
[c]*Centro de Ciencias Aplicadas y Desarrollo Tecnológico, Universidad Nacional Autónoma de México, Mexico*

Received June 8, 2009; accepted June 15, 2009
Available online September 6, 2009

KEYWORDS
Dyslexia;
Central Auditory Processes Diseases;
Phonologic processing

Abstract
Objectives: The aim is to assess the ability to discriminate words, using 2 psychoacoustic verbal tests of Central auditory processes in Spanish: Binaural Fusion Test (BFT; PFB in its Spanish version) and Filtered Word Test (FWT; PPF in its Spanish version) in children with dyslexia and controls.
Methods: One group of 40 dyslexic children who were receiving therapy for dyslexia at the time of the tests. Forty children without dyslexia were selected as controls, out of 298 children who attended a public school.
Results: The rate of males to females was 2/1 in the dyslexic group. The average correct answers for the BFT were 65%66%in dyslexic group and 75%80%in the control group. For the FWT, they were 50%54%in the dyslexic group and 67%71%in the control group (Student t <.05).
Conclusions: These results contribute to making disorders in central auditory processing in children with dyslexia evident. We suggest using the tests with each patient in order to elaborate a rehabilitation plan.

*Corresponding author.
E-mail address: yploza@yahoo.com.mx (Y.R. Peñaloza-López).

PALABRAS CLAVE
Dislexia;
Procesos auditivos centrales;
Prueba de fusión binaural;
Prueba de palabra filtrada;
Español;
Procesamiento fonológico

Procesos centrales de la audición evaluados en español en escolares con dislexia y controles. Pruebas de fusión binaural y de palabras filtradas

Resumen
Objetivo: El objetivo es evaluar la habilidad para distinguir palabras usando dos pruebas psicoacústicas verbales de procesos centrales de la audición (PCA) en español: la prueba de fusión binaural (PFB) y la prueba de palabra filtrada (PPF), en niños con dislexia y en niños controles.
Métodos: Cuarenta niños con dislexia seleccionados de grupos de terapia y 40 niños seleccionados de 298 niños de una escuela pública como controles, pareados por sexo y edad. Resultados: Hubo predominio masculino 2/1 en los niños disléxicos. Los promedios de acierto para la PFB fueron del 65 al 66% para los niños con dislexia y del 78 al 80% para los niños control. Para la PPF éstos fueron del 50 al 55% para los niños con dislexia y del 67 al 71% para los controles (t de Student <0,05).
Conclusiones: Estos resultados contribuyen a evidenciar alteraciones de los PCA para estímulos psicoacústicos verbales en niños con dislexia. Se propone evaluar cada paciente con pruebas de PCA para definir el plan de rehabilitación.

Introduction

This study is part of a research line on central auditory processes (CAP), specifically with psychoacoustic tests, which in this case are the binaural fusion test (BFT) and the filtered speech test (FWT).

The definition of CAP is currently regarded as evolving and has received criticism regarding the implications of various functions in the assessment procedures, as well as regarding the psychoacoustic operating procedures.[1-6] The ASHA (1996) released the definition of CAP as the auditory mechanisms and processes responsible for localization and lateralization, discrimination, pattern recognition, and temporal aspects of hearing (resolution, masking, integration), as well as the deterioration of auditory performance due to competition signals or degraded signals.[7]

In relation to dyslexia, Norman Geswind made the first references to the neuro-anatomical bases of this clone entity, which followed the line of investigation and neuro-anatomical reports of cases studied by Galaburda, whose main goal focused on etiological agents such as immune factors, adverse perinatal conditions and, recently, abnormal neuronal migration in relation to genetic factors.[8-10] These studies highlight the predominant abnormalities in brain areas that involve language functions.[11-16]

Diagnostic imaging studies have explored the anatomy of word processing. From the results, it is proposed that the anterior regions of the brain, the frontals, are areas related to the lexical-semantic process, while the posterior are focused more towards comprehension.[17] Regarding laterality and language, studies with functional MRI (fMRI) have appreciated that language tasks can activate many brain areas, with a predominance, which is not exclusive, of the left hemisphere. The brain activation patterns differ between dyslexics and controls. Dyslexics show less activation in the posterior regions (Wernicke's area, angular gyrus, striate cortex) and relative overactivation in the anterior region (inferior frontal gyrus). It has been suggested that phonological disorders participate in dyslexia and that these activation patterns provide a specific neural behavior of this defficiency.[18-20]

Regarding the phonological basis of dyslexia, it should be considered that the reading acquisition process requires the awareness that spoken words can be divided into phonological constituents, which in turn represent the alphabetic characters. Such phonological awareness seems to be characteristically absent in dyslexic subjects.[18] Phonological awareness has been conceptualized as a complex cognitive process that involves auditory recognition, phonological processing, visual memory, auditory memory, and superior verbal processes, in addition to visual implications.[20]

In children with dyslexia, numerous reports offer evidence of CAP alterations, both in studies with psychoacoustic tests and in electrophysiological tests.[21-26]

BFT, a model for evaluating CAP, was originally described by Matzke in 1959.[27] It has been widely used by Katz, using words as stimuli in the tiered spondaic form.[28] A significant advantage of this test is that it is a dichotic test, which uses pass-bass frequencies in one ear and pass-acute frequencies in the opposite ear. The studies cited by Katz (2004) show average rates of performance in the English version of this type of test, in children from 7 to 10 years, of between 76% and 87% for those of the higher age. Singer notes 70.9% at 7 years to 86.7% for 11 to 13 years, while for the same years with learning disorders, from 45% to 71%.[29]

The FWT was already used in the original studies by Bocca and Calearo in 1954[30]; it is the oldest model of testing with decreased verbal redundancy. Its usefulness has been proven in numerous studies that give evidence of flaws in the CAP for verbal material.[29,31]

The aim of this paper is to assess the skills required to correctly repeat two psychoacoustic verbal tests of CAP in Spanish—the BFT and the FWT—in children with dyslexia and control children.

Material and methods

In this prospective and transversal study, cases were studied after informed consent. We considered 80 children, 40 of them with medical diagnosis of dyslexia (DSM-IV),[32] established by a certified specialist, who attended therapy at the same institution at which they were diagnosed (National Rehabilitation Institute, located in Mexico City), and 40 control group children matched by age and gender in 1 to 1 proportion, except for slight variations, as shown in Table 1. Gender: fifty-four children were male, of whom 28 had dyslexia and 26 were controls. The female cases were 26, of whom 12 had dyslexia and 14 were controls. The control group children were selected from an official school population of 298 children; all were assessed for reading and writing skills, without finding specific disorders (DSM-IV). Cases with risk factors due to neurological damage or otologic pathology were eliminated and those remaining had no severe emotional disorders or concomitant neurological disease. Bilateral hearing was normal, since in no case did the children with dyslexia or the control group children have average tonal thresholds for 0.5; 1, and 2 kHz on each side above 20 dB HL.[33] WISC-R showed normal IQ in all cases and all underwent both tests (BFT and FWT) in the CAP laboratory.

The test verbal material included in the BFT and the FWT is from the original study by Castañeda et al (1987)[34]; therefore, the selection of words for the BFT were disyllables with the combination of the most commonly used phonemes in the Spanish spoken in Mexico City. The stimuli applied during the FWT were monosyllables, most with no meaning, retaining the combination of the most used phonemes in Mexico City Spanish. The lists and recordings were developed on CD by voice professionals at the facilities of the Acoustics Laboratory of the Centre for Applied Sciences and Technological Development of the Universidad Nacional Autónoma of México (CCADET-UNAM).[35-37] They were reproduced in a sound-damped chamber, starting with a calibration track applied through an Amplaid 460 audiometer. The stimulus was applied to the studied child through TDH headphones. The tracks on the CD consisted of 25 words, applied at 50 dB SL re/ threshold of 1 kHz.

- The PFB consisted of 8 recorded lists of tracks with 25 words, which were disyllabic, with meaning and phonetically balanced. The words were split into pass-bass that were presented to one ear and pass-acute presented to the opposite ear.[38] Some example words of these listings are: *calor, flaca, pista, saco* (hot, skinny, runway, sack).
- The FWT with pass-bass was based on the same published scheme (Vazquez, 2003; Benavides, 2007[39]), consisting of tracks with 8 listings of 25 words, mostly without meaning and monosyllabic and obtained under phonetic balancing through computation programs from the initial study sample used by the Spaniard Castañeda. White noise was applied in the opposite ear at -30dB compared to white stimulus. Some examples of these listings are: te, cur, ka, lo.
- The publication of Vazquez and Peñaloza (2003) describes the psychoacoustic characteristics of these tests: the BFT contains pass-bass and pass-acute and the FWT only pass-bass.

The child in the study was also asked to exactly repeat the word or word fragment that he/she heard, integrated binaurally in the BFT and monaurally in the FWT. Two lists were applied in each test, one on each ear; in the case of BFT, it was scored according to the ear in which the pass-bass was applied and in FWT, according to the ear in which the white stimulus was applied. The study was always started on the right side.

The test conductor, placed next to the child during the study but out of their possible reading sight, verified the list of words and the accuracy of repetition of each stimulus applied. In case of error, this was scored next to the corresponding stimulus. The percentage of accuracy for the right ear and left ear was quantified for each list.

The analysis of results was performed based on SPSS 12; the averages of central tendency and dispersion were determined by the Student *t* test for independent variables. The significance of the difference between the groups of children with dyslexia and without dyslexia was determined as $P<.05$.

Results

The age and gender distribution of cases of dyslexia (n=40) and control cases (n=40) included in the study are noted in Table 1. Children 8 and 9-years-old are distinguished by their frequency, since they formed 56% of each group. This situation reflects the predominance of children of this age in the rehabilitation services of the institution, and as a group also represents the policies of acceptance to therapy services.

There was 2/l male predominance in children with dyslexia, since 70% of the groups were male.

The success averages for the BFT were 65%-66% for children with dyslexia and 78%-80% for control children. For the FWT, they were 50%-55% for children with dyslexia and 67%-71% for controls (Student *t* test <.05).

Table 2 shows the averages of the success rates and the corresponding standard deviation for each test (BFT and

Table 1 Distribution of children with dyslexia and control children according to age and gender

Age	Male		Female		Total	
	D	C	D	C	D	C
7	8	6	1	3	9	9
8	7	7	4	4	11	11
9	8	7	3	4	11	11
10	3	4	4	3	7	7
11	1	1	0	0	1	1
12	1	1	0	0	1	1
Total	28	26	12	14	40	40

C indicates controls; D, dyslexics.

Table 2 Results obtained on the arithmetic average for the percentage of correct answers for each test applied, by ear (SPSS 12)

	Study group	No.	Average	Standard deviation
Binaural fusion right, %	Dyslexics	40	65	21
	Control	40	78	15
Binaural fusion left, %	Dyslexics	40	66	19
	Control	40	80	12
Filtered words right, %	Dyslexics	40	55	20
	Control	40	71	15
Filtered words left,(%	Dyslexics	40	50	17
	Control	40	67	14

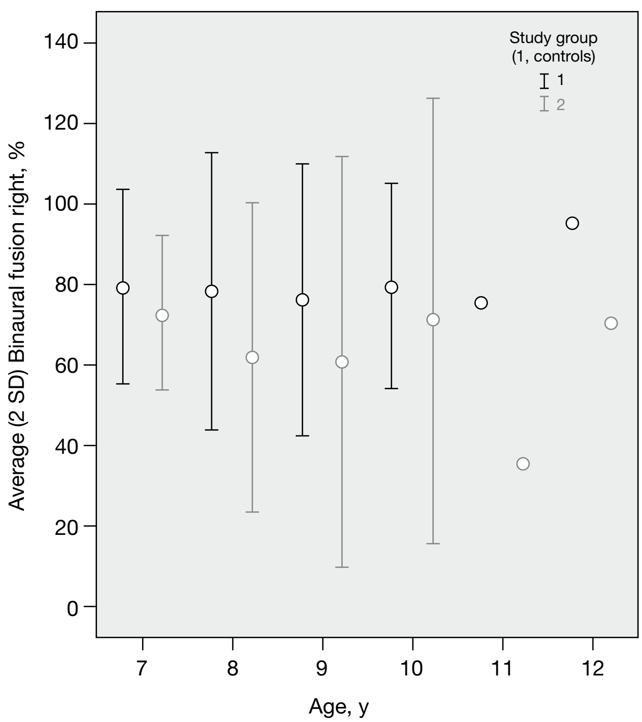

Figure 1 Average and 2 SD of correct answers by years of age for the binaural fusion test (BFT) and the right ear.

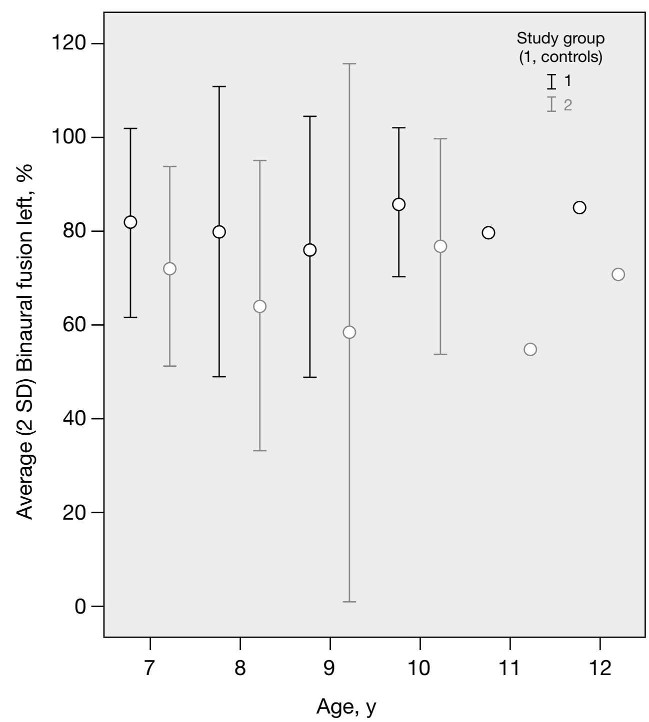

Figure 2 Average and 2 SD of correct answers by years of age for the BFT and the left ear.

FWT) and each side, as well as for the group of children with dyslexia (n=40) and the group of control children (n=40).

It can be observed that there is a constant difference between the 2 groups studied and the percentages of children in the control group are always better.

The distribution of average values of accuracy, by BFT or FWT, by left and right ears and by age groups, is shown in Graphs 1, 2, 3, and 4 (Figures 1-4). The distribution corroborates differences between the group of children with dyslexia and the control group. It should be noted that the 2 categories of older age contain only 1 child. It is likely that these children have a more severe literacy disorder. These graphs representing the results of accuracy of both tests and both sides show an approximately stable trend in the scores between 7 and 12 years of age; this is especially notable between 7 and 10 years of age, which are the age groups containing most of the children studied.

Considering the information contained in Table 2 and Graphs 1-4 and comparing the accuracy scores between the BFT and the FWT, lower accuracy scores are evident for the FWT with respect to the BFT. This seems to be related to greater difficulty in the test stimuli, since for BFT the words are disyllabic, whereas for FWT words are monosyllables, most of them meaningless. The differences between the 2

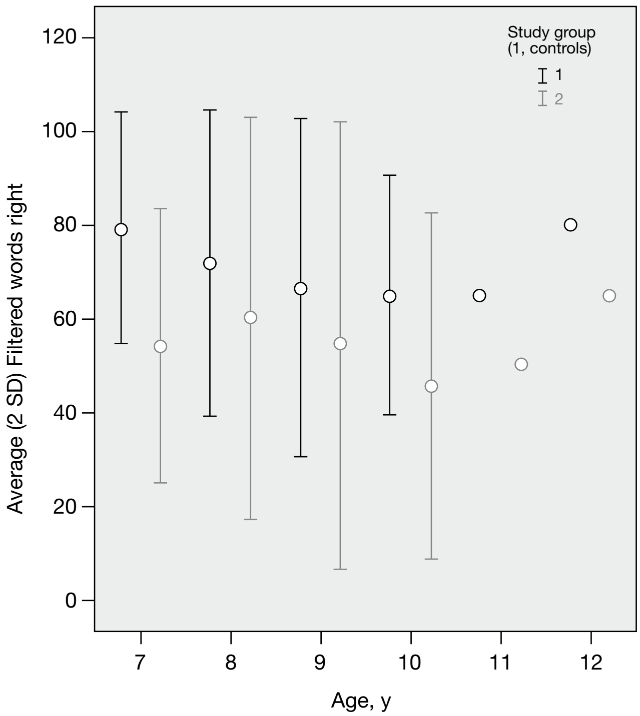

Figure 3 Average and 2 SD of correct answers for the FWT, by years of age and the right ear.

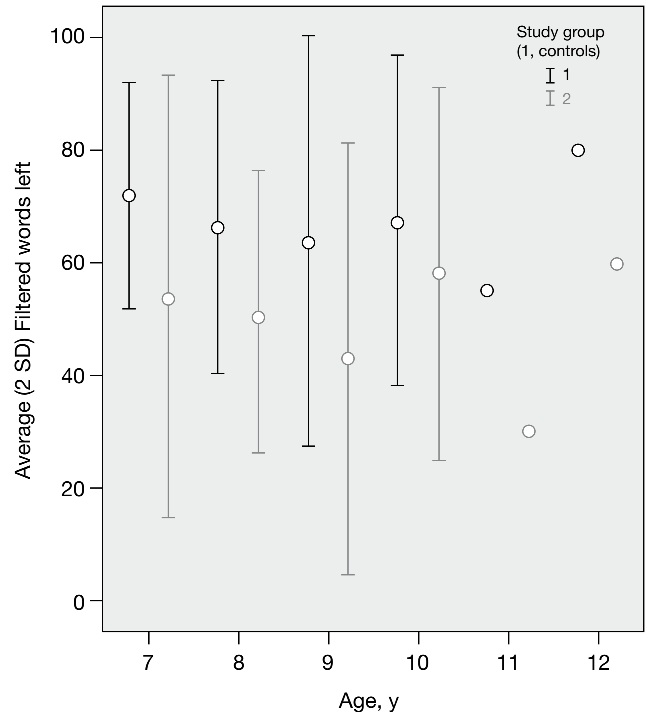

Figure 4 Average and 2 sd of correct answers for the FWT, by years of age and the left ear.

Table 3 Sample of the significance of the difference obtained for each test and ear between the group of control children and the group of children with dyslexia, and confidence interval of the difference (SPSS12)

	t for independent samples			
	Levene's test	Significance (2 tails)	95% confidence interval of the difference	
			Minor	Major
Binaural fusion right, %	Equality of variances	0.002	-25.31	-6.28
Binaural fusion left, %	Equality of variances	0.00	-19.88	-3.36
Filtered words right, %	Equality of variances	0.0001	-25.76	-7.92
Filtered words left, %	Equality of variances	0.0001	-28.88	-10.98

tests (Student *t* test for independent samples) considering the right BFT/FWT, showed a *P* value of .005. The same relationship for the left tests generated a *P* of .0001. This result supports the qualitative observation and relates to the average scores for the left side for FWT being lowest (Table 3).

Moreover, no significant differences are noticeable between right and left scores inside either test, and the Student *t* test results were $P > .05$.

From these results, it should be emphasized that significant differences in the Student's t-test were observed between the group of children with dyslexia and control group children. However, the differences were greater for the FWT (Table 3).

Discussion

The analysis of the results obtained in this study denotes, as usual in clinical experience and classic reports in the field, the prevalence of this literacy disorder in the male gender.[9]

The result per gender also makes other differences manifest, as regards their performance in the verbal tests for the CAP study that were applied. Children diagnosed with dyslexia do not have impaired verbal expression, which orientates towards the existence of phonological implications in some language pathology conditions. However, it is assumed that, in dyslexia, the substrate of their literacy limitations involves phonological processing, as has already been concluded in various English language publications.[18,20,21] It is the characteristic differences of phonological analysis observed between the English and Spanish languages that create an interesting condition in this study. In the English language, phonological representation is generally different from that of the grapheme, while in Spanish the usual pattern is similar or direct representation. These features create the need to study discrimination and correct repetition of words and monosyllables, mostly without meaning, in children with dyslexia in our environment. On the other hand, the need to evaluate these functions in other languages besides English, in order to note possible differences, is also recognized. It is also conceded that even within the Spanish language it may be necessary to apply these tests based on a familiar lexicon specified by region.

We also consider interesting the study of word processing through strictly designed, audiological tests applicable to the CAP study, created from a pattern of the use of Spanish in our country, from which the test lists were made, according to the requirements of familiarity and balance of usual phonemes[34-37] (phonetically balanced). The selection of information by ear is useful for studies of laterality and spatial orientation, which has already been published by this study group (Olivares, 2005).[40] The few differences between the performance of left and right ears for the BFT can be attributed to the physiological condition implicit in the frequency range being applied to each ear. In this sense, it is worth analyzing whether it remains appropriate to designate the side of the study in the BFT according to the pass-bass or if it should be defined by the pass-acute, which seems to offer better word discrimination results.

The decrease in the frequency of the problem with increasing age, observed in this study, may be related in this case with institutional criteria for rehabilitative care, which have a limited duration. However, it also should be noted that on this point there is a perception that the child usually generates learning strategies to meet their limitations in literacy. Interestingly, in this study it can be observed that the percentages of success obtained do not show a trend toward increase as could be expected physiologically by maturation effects. This may mean that in this age range, between 7 and 12 years old, stable processing of verbal stimuli is obtained.

The individual success values also make it clear that there are control cases that apparently function as carriers of disorders in verbal stimuli processing, although there is no impact on their literacy skills. This may mean that there are many categories or forms of these disorders, which ultimately makes the phenomenon being studied far more complex.

Detailed analysis of individual values obtained also makes it clear that scores obtained are not always symmetrical between right and left and eventually there is marked asymmetry. According to previous studies,[40] these findings could also be related to auditory laterality; however, we believe that the implementation of other tests, such as that of dichotic digits, is more valid to define auditory laterality. These concepts on auditory laterality have been known since the original works of Kimura.[41]

In connection with the implementation of a value for each case while avoiding the arbitrary definition of a single ear, as well as not assigning an average value for both ears, a common alternative in audiology is to select only the better ear to score the subject. However, this does not seem a precise procedure, nor is classifying the case based on the performance of the worse ear. These observations represent an obstacle at the time of scoring sensitivity and specificity in clinical entities that may achieve the gold standard.

In this case, the average values identified for each of the study groups, according to type of evidence and ear (SPSS 12), indicate differences between children with dyslexia and control group children. However, standard deviations are wide, especially in the group of children with dyslexia.

Lastly, we would like to highlight the average success rates obtained for each test. For BFT these were 65%-66% for children with dyslexia and 78%-80% for control children. These values are higher than those obtained with the FWT, which for children with dyslexia were 50%-55% and for control children, 67%-71%. It should be emphasized that, while in the FWT the most affected side of the dyslexic children was the left side, in the PFB it was the right side; however, the difference was only 2% and the possible reasons have already been discussed, as regards the frequency content of the pass-bass and pass-acute. Comparing the results we have mentioned with the lessons learned from the medical literature, we note that in the report by Singer et al (1998), considering 238 cases of normal children with learning impairments for reading and writing, cut points were obtained by years of age, which were progressively higher with increasing age of the child. In order to achieve a useful comparative effect, results were averaged determining 75.4% as the cutoff point for the BFT and 68% for the FWT. These values seem very close to those obtained in this study for the BFT and match those for the FWT. Chermak and Musiek (1997) recorded 70% as a cutoff point for the FWT.[42]

In conclusion, the information obtained and the values of $P<.05$ for all four variants of the BFT and FWT evidence obtained for each ear (Student *t* test) between the group of children with dyslexia and the control group strengthens the hypothesis that these study procedures for the review of the disabilities of children 7 to 11 years of age for the correct repetition of verbal stimuli are marking an important area, though certainly not unique, in auditory processing disorders. These findings can serve as a guide towards the use of rehabilitative resources aimed at addressing these shortcomings.

Acknowledgments

For the collaboration of the medical services of speech pathology and area of speech pathology rehabilitation at the National Institute of Rehabilitation. To linguist G. Lorandi for reviewing the document.

Conflict of interests

There are no conflicts of interests. There is no external funding.

References

1. Belis JT. Assessment and management of central auditory processes disorders in the educational setting: From science to practice. USA: Delmar Cengage Learning. 2002. p. IX-XII.
2. Cacace AT, McFarland DJ. Central auditory processing disorder in school-aged children: A critical review. J Speech Lang Hear Res. 1998;41:355-73.
3. Mc Farland D, Cacace A. Modality specificity as a criterion for diagnosing central auditory processing disorders. Am J Audiol. 1995;4:36-48.
4. Cacace A, Mc Farland D. The importance of modality specificity in diagnosing central auditory processing disorder. Am J Audiol. 2005;14:112-23.
5. Friel-Patti S. Clinical decision making in the assessment and intervention of central auditory processing disorders. Lang Speech Hear Serv School. 1999;30:345-52.
6. Musiek F, Bellis T, Chermak G. Nonmodularity of the central auditory nervous system: Implications for (central) auditory processing disorder. Am J Audiol. 2005;14:128-38.
7. American Speech-Language-Hearing Association. Central auditory processing: Current status of research and implications for clinical practice. Am J Audiol. 1996;5:41-54.
8. Galaburda AM, Kemper TL. Cytoarchitectonic abnormalities in development dyslexia. Ann Neurol. 1979;6:94-100.
9. Galaburda A, Cestnick L. Dislexia del desarrollo. Rev Neurol. 2003;36:S3-9.
10. Galaburda AM. Dislexia a molecular disorder of neuronal migration: The Norman Geschwind Memorial Lecture. Ann Dyslexia. 2005;55:151-63.
11. Ortiz Alonso T, Maestu F, Fernandez-Luca A, Amo C, Campo P, Capilla-Gonzalez A, et al. Neuromagnetic correlates of dyslexia. Rev Neurol. 2003;36:S10-2.
12. Castaño J. Neurobiological bases of language and its disorders. Rev Neurol. 2003;36:781-5.
13. Lopez-Escribano. Contribuciones de las neurociencias al diagnostico y tratamiento educativo de la dislexia. Rev Neurol. 2007;44:173-80.
14. Lozano A, Ramírez M, Ostrosky-Solis F. Neurobiología de la dislexia del desarrollo: una revisión. Rev Neurol. 2003;36: 1077-82.
15. Miranda Casas A, Baixauli-Ferrer I, Soriano M, Presentación-Herrero MJ. Cuestiones pendientes en la investigación sobre dificultades del acceso léxico: una visión del futuro. Rev Neurol. 2003;36:S20-8.
16. Heiervang E, Hugdahl K, Steinmetz H, Smievoll AI, Stevenson J, Lund A, et al. Planum temporale, planum parietale and dichotic listening in dyslexia. Neuropsych. 2000;38:1704-13.
17. Posner MI, Pavese A. Anatomy of word and sentence meaning. Proc Natl Acad Sci USA. 1998;95:899-905.
18. Shaywitz S. Dyslexia. N Engl J Med. 1998;338:307-12.
19. Tuchman RF. Correlatos neuroradiologicos e imagenologicos de resonancia magnética funcional con la dislexia del desarrollo. Rev Neurol. 1999;29:322-6.
20. Etchepareborda MC. La intervención en los trastornos disléxicos: entrenamiento de la conciencia fonologica. Rev Neurol. 2003;36:S13-9.
21. Serniclaes W, Sprenger-Charolles L, Carró R, Demonet JF. Perceptual discrimination of speech sounds in developmental dyslexia. J Speech Lang Hear Res. 2001;44:384-99.
22. Chermak G. Deciphering auditory processing disorders in children. Otolaryngol Clin N Am. 2002;35:733-49.
23. Griffiths T. Central auditory pathologies. Br Med Bull. 2002;63:107-20.
24. Wimmer H, Hutzler F, Wiener C. Children with dyslexia and right parietal lobe dysfunction: Event-related potentials in response to words and pseudowords. Neurosc Lett. 2002;331:211-3.
25. Bradlow AR, Kraus N, Hayes E. Speaking clearly for children with learning disabilities: Sentence perception in noise. J Speech Lang Hear Res. 2003;46:80-97.
26. Zenker F, Barajas JJ. Las funciones auditivas centrales [en Unea]. Auditio: Revista Electrónica de Audiologóa. 2003;2: 31-41. Available from: http://auditio.com.revista/pdf/vol2/2/02023.pdf.
27. Katz J, Ivey R. Spondaic procedures in central testing. In: Katz J, editor. Handbook of clinical audiology. 4 ed. USA: William & Wilkins; 1994. p. 239-55.
28. Matzker J. Two methods for assessment of central auditory functions in case of brain disease. Ann Otl Rhinol Laryngol. 1959;68:1155-97.
29. Singer J, Hurley R, Preece J. Effectiveness of central auditory processing tests with children. Am J Audiol. 1998;7:73-84.
30. Bocca E, Calearo C, Cassinari V. A new meted for testing hearing in temporal lobe tumors. Acta Otolaringol. 1954;44:219-21.
31. Muller G, Bright K. Monosyllabic procedures in central testing. In: Katz J, editor. Handbook of Clinical Audiology. 4 ed. USA: Williams & Wilkins; 1994. p. 22-238.
32. DSM-IV. Manual diagnóstico y estadístico de los trastornos mentales. Barcelona: Editorial Masson; 1995. p. 50-56.
33. Willems P. Clasification of hearing loss. New Engl J Med. 2000;342:1101-9.
34. Castañeda R. Análisis estadístico del español. Inteligibilidad y una aplicación a la acústica de recintos [tesis de licenciatura]. Mexico: UNAM; 1987.
35. Castañeda R, Perez SJ. Analisis fonético de las listas de palabras de uso más extendido en logoaudiometría. An ORL Mex. 1991;XXXVI:23-30.
36. Perez SJ, Castañeda R, Escamilla A. Estudio experimental sobre el reconocimiento auditivo de monosílabos sin sentido y bisílabos, ambos fonéticamente balanceados. Rev Mex Ing Biomed. 1997;XVIII:11-6.
37. Pórez SJ, Castañeda R, Peñaloza Y. Logoaudiometría. Una revisión necesaria. An ORL Mex. 1990;4:282-9.
38. Vázquez-Spude S, Peñaloza-López Y, Perez JJ, García-Pedroza F. Prueba de fusión binaural en español, aplicada a sujetos normales y a casos con lesiones del lóbulo temporal o con esclerosis múltiple. Rev Mex Neuroci. 2003;4:234-41.
39. Benavides M, Peñaloza Y, Jimónez de la Sancha S, Garda Pedroza F, Gudino PK. Lateralidad auditiva y corporal, logoaudiometría y ganancia de audífono monoaural. Aplicación en hipoacusia bilateral simótrica. Acta Otorrino. 2007;58:458-63.
40. Olivares-Garda MR, Peñaloza-López YR, Garcóa-Pedroza F, Jesus Pórez S, Uribe Escamilla R, Jimenez de la Sancha S. Identificación de la lateralidad auditiva mediante una prueba dicotica nueva con dígitos en español, de la lateralidad corporal y orientación espacial en niños con dislexia y en controles. Rev Neurol. 2005;41:198-205.
41. Kimura D. Cerebral dominance and the perception of verbal stimuli. Canad J Psicol. 1961;15:166-77.
42. Chermak G, Musiek F, Chie Higuchi C. Central auditory processing disorders. Albany NY: Edit Singular; 1997.