Processamento temporal auditivo: relação com dislexia do desenvolvimento e malformação cortical******

Temporal auditory processing: correlation with developmental dyslexia and cortical malformation

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Abstract

Background: temporal auditory processing and developmental dyslexia. Aim: to characterize the temporal auditory processing in children with developmental dyslexia and to correlate findings with cortical malformations. Method: twenty school-aged children, ranging in age from 8 to 14 years were evaluated. These children were divided into two groups: the experimental group (EG) was composed by 11 children (eight were male) with developmental dyslexia and the control group (CG) was composed by nine normal children (six were male). After neurological assessment and verification of the intellectual level, language, reading and writing skills in order to determine the diagnosis, children underwent a peripheral audiological evaluation and Random Gap Detection Test and/or Random Gap Detection Test Expanded. Results: a statistically significant difference between children in the EG and CG were observed, with children in the EG presenting worst performances. Most of the children in the EG presented perisylvian polymicrogyria. Conclusion: children with developmental dyslexia may present temporal auditory processing disorders with deficits in phonological processing. Cortical malformations may be the anatomical substrate of these disorders.

Key Words: Dyslexia; Hearing; Child.

Resumo

Tema: processamento temporal auditivo e dislexia do desenvolvimento. Objetivo: caracterizar o processamento temporal auditivo em escolares com dislexia do desenvolvimento e correlacionar com malformação cortical. Método: foram avaliados 20 escolares, com idade entre 8 e 14 anos, divididos em grupo experimental (GE) composto por 11 escolares (oito do gênero masculino) com o diagnóstico de dislexia do desenvolvimento e grupo controle (GC) composto por nove escolares (seis do gênero masculino) sem alterações neuropsicolinguísticas. Após avaliações neurológica, neuropsicológica e fonoaudiológica (avaliação de linguagem e leitura e escrita) para obtenção do diagnóstico, os escolares foram submetidos à avaliação audiológica periférica e posteriormente aplicou-se o teste *Random Gap Detection Test* e/ou *Random Gap Detection Test Expanded*. Resultados: observou-se diferença estatisticamente significante entre os escolares do GE e GC, com pior desempenho para o GE. A maioria dos escolares do GE apresentou polimicrogiria perisylviana. Conclusão: escolares com dislexia do desenvolvimento podem apresentar alterações no processamento temporal auditivo com prejuízo no processamento fonológico. Malformação do desenvolvimento cortical pode ser o substrato anatômico dos distúrbios.

Palavras-Chave: Dislexia; Audição; Criança.

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Introduction

Temporal auditory processing is the ability of the auditory system to process changes in acoustic signals occurring over time as well as the ability to process brief transient acoustic events[1].

Developmental dyslexia is a disorder of neurogenetic origin characterized by a deficit in phonological processing leading to a difficulty in the decoding and recognition of words. It affects patients' reading and writing skills but does not necessarily interfere with cognitive and academic performance. It is the most prevalent learning disorder[2,3].

Studies have described language and learning disorders occurring in correlation with abnormalities in cortical development. Changes in neuronal migration and cortical organization were observed in four postmortems conducted on brains of dyslexic patients. The most consistent findings were ectopy and occasional microgyria, mainly affecting the perisylvian region of the left hemisphere[4]. Magnetic resonance imaging identified perisylvian polymicrogyria in families with histories of language and learning disabilities[5,6].

Studies with animals show that phonological deficits in language disorders can be a consequence of deficits in temporal auditory processing. Bilateral microgyria has been associated with deficits in temporal auditory processing in rats[7,8].

Several theories attempt to understand etiology, diagnosis and therapeutic intervention for dyslexia through cytoarchitectonic, genetics and neuroimaging studies. The phonological theory suggests a failure in the processing of phonological information, for example, deficits in cognitive functions due to the involvement of attention and memory processes[9]. Other theories based on the magnocellular visual deficit[10,11], temporal auditory processing deficit[12,13], cerebellar deficit[14] or a general sensorimotor dysfunction[3] have suggested that phonological processing is not always sufficient to explain alterations in reading and writing abilities, suggesting that sensorimotor skills are important for reading[3,15].

As this study refers to auditory and phonological processing, the aim was to characterize temporal auditory processing in school-age children with developmental dyslexia and to correlate this with malformations of cortical development.

Method

This study was carried out at the Clinical Hospital of the University of Campinas (UNICAMP), Brazil, after being approved by the Ethics Committee of the same university (protocol 196/2003). The study was conducted from May 2007 to October 2008.

Twenty school-age children ranging from 8 to 14 years of age participated in the study. The experimental group (EG) consisted of 11 children (eight males and three females) with developmental dyslexia and the control group (CG) consisted of nine normal children (six males and three females). To obtain the diagnosis of developmental dyslexia the EG children were subjected to neurological, intellectual, audiological and speech assessments.

The developmental history questionnaire was answered by parents and included questions about neuropsychomotor development, family history of language and learning delay, and demonstrated difficulty in understanding speech in noisy situations, requests for repetitions and difficulty following directions.

A detailed clinical pediatric neurological assessment for pseudobulbar signals (abnormal history of drooling, choking, and sucking difficulty during the first years of life) was conducted. Magnetic resonance imaging (MRI) scans were performed in a 2.0 T scanner (Elscint Prestige) with posterior multiplanar reconstruction and curvilinear reformatting in 3D.

The intelligence quotient was measured according to the Wechsler Intelligence Scale for Children-WISC-III[16]. The criteria was nonverbal IQ > 80 because it best represents the cognitive ability of these children.

The language evaluation measured phonologic, syntactic, semantic and pragmatic language aspects. The tests and protocols used were:

. Sample of free speech: to observe the phonological, morphosyntatic, semantic and pragmatic aspects of language and associate them to standardized tests.
. ABFW - Children Language Test with phonological test[17]: imitation and naming. The words were phonetically transcribed and analyzed using phonological processes.

The reading/writing evaluation included:

. Sample of free writing: this test indicated children's capacity for producing coherent essays. Children were free to choose their own themes.

Word transposition, word exclusion, graphemes transposition, grammar and quality of writing were assessed.

. Phonological awareness: evaluated using the Phonologic Skill Test18. The test consists of 10 sub-tests, each composed of four items measuring capacity for analysis (initial, middle and final), addition (syllables and phonemes), segmentation (phrasal and lexical), exclusion (syllables and phonemes), transposition, rhymes reception, rhymes sequence, syllabic reversal and articulation image.

. Syntactic awareness: evaluated using the Syntactic Awareness Test19. The test consists of four subtests: grammatical trial, grammatical correction, grammatical sentences correction with incorrect grammar and semantics and categorization of words, with the aim of evaluating meta-syntactic ability.

. Oral reading, writing and arithmetic: evaluated using the School Performance Test20. Age appropriate oral reading, writing and arithmetic sub-tests were used.

. Non-words reading and writing: performed by reading and writing 40 non-words composed of two syllables, three syllables and four syllables, with a low, medium and high degree of similarity with words21.

. Oral speed-reading: to assess oral reading ability and reading comprehension22.

Participants underwent a peripheral audiological evaluation consisting of: pure tone audiometry, speech reception threshold, speech recognition scores, acoustic impedance and acoustic reflex research. For the peripheral audiological evaluation an acoustic cabin, AC-30 audiometer (Interacoustics) and impedance audiometer AT235h (Interacoustics) were used. In children with normal peripheral hearing (threshold < 25 dB), temporal resolution tests were applied.

After confirming the diagnosis of dyslexia, nonverbal IQ > 80 and normal peripheral hearing in the EG and the absence of neuropsycholinguistic deficits in the CG, temporal auditory tests were applied which took into consideration children's age and hearing development. Two-channel AC-30 audiometers (Interacoustics), a Phillips CD player and an acoustic cabin were used. The temporal auditory tests applied were: Random Gap Detection Test (RGDT) and/or Random Gap Detection Test Expanded (RGDT-Exp).

The Random Gap Detection Test is a temporal resolution test that analyzes the ability of the auditory system to detect rapid changes in sound stimulus or the shortest time necessary to discriminate between two acoustic stimuli. The auditory gap detection threshold of tones is obtained when the subject identifies signal pairs separated by a time interval of between zero and 40 milliseconds presented in random order. The subject is supposed to identify whether the two stimuli are heard as one sound or two23. The test includes tonal stimuli at four frequencies (500, 1000, 2000, and 4000 Hz).

The Random Gap Detection Test - Expanded is intended for individuals whose gap detection threshold exceeds 40 milliseconds. It includes the time interval between 50 and 300 milliseconds and is administered in the same manner as the standard Random Gap Detection Test23.

Statistical analysis was performed using the Mann-Whitney test, with a level of significance of 0.05.

Results

Of the 11 children with dyslexia the MRI showed bilateral perisylvian polymicrogyria in seven (Figure 1). Age, gender, family history of dyslexia and MRI data for these children are presented in Table 1.

The average age of the children in the two groups was homogeneous. The mean age of the EG was 126.64 months (SD=22.36) and of the CG was 131.22 (SD=26.30). There was no statistically significant difference in age among the groups (p=0.7).

Among the eleven children in the EG, eight were boys and three were girls, all children were right handed and cases 1, 2, 3 and 4 reported pseudobulbar signs. Cases 2, 4, 6, 7, 8, 9, 10 and 11 had a family history of dyslexia.

Analysis of reading and writing abilities are presented in Table 2. Findings suggest a statistically significant difference in phonological and syntactic awareness, reading and writing of real words and non-words and oral speed reading. Only case 5 had adequate reading comprehension. There was no statistically significant difference in arithmetic abilities.

The children in the EG had poor performance reading irregular words and non-words. Correlating this with phonological and auditory processing and considering the region affected by the cortical abnormality (cases 1, 2, 3, 4, 8, 9 and 11) it was considered that the children had phonological dyslexia.

There was also a statistically significant difference between the groups (Table 2) regarding temporal auditory processing, serving as evidence of temporal auditory processing damage in children with dyslexia.

FIGURE 1. Figure illustrative magnetic resonance imaging showing bilateral perisylvian polymicrogyria

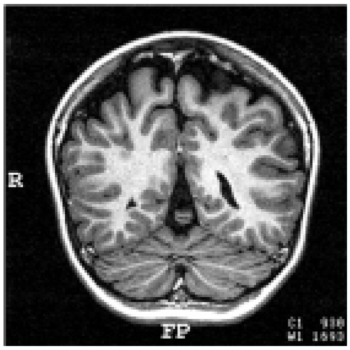

TABLE 1. Characteristics of children with dyslexia.

Case	Age (years)/gender	Family history of dyslexia	Magnetic resonance imaging
1	8/male	-	Perisylvian polymicrogyria
2	8/ male	+	Perisylvian polymicrogyria
3	8/female	-	Perisylvian polymicrogyria
4	10/ male	+	Perisylvian polymicrogyria
5	10/ male	-	Normal
6	10/ male	+	Normal
7	11/ female	+	Normal
8	11/ female	+	Perisylvian polymicrogyria
9	12/ male	+	Perisylvian polymicrogyria
10	12/ male	-	Normal
11	14/ male	+	Perisylvian polymicrogyria

TABLE 2. Results of reading, writing and temporal auditory tests.

Abilities	Group	N	Mean	SD	(p)
Phonological test (PST)	EG	11	62.36	9.56	
	CG	9	70.33	4.15	**0.016***
	Total	20	65.95	8.48	
Syntactic test (SAT)	EG	11	40.91	5.47	
	CG	9	47.89	5.06	**0.016***
	Total	20	44.05	6.26	
SPT (writing)	EG	11	12.09	6.12	
	CG	9	27.78	5.19	**< 0.001***
	Total	20	19.15	9.76	
SPT (reading)	EG	11	42.73	20.98	
	CG	9	65.56	3.47	**< 0.001***
	Total	20	53.00	19.30	
SPT (arithmetic)	EG	11	19.09	5.82	
	CG	9	23.33	9.39	0.361
	Total	20	21.00	7.73	
Nonwords (writing)	EG	11	19.45	10.41	
	CG	9	36.11	2.32	**0.001***
	Total	20	26.95	11.47	
Nonwords (reading)	EG	11	21.64	8.41	
	CG	9	36.56	2.24	**0.001***
	Total	20	28.35	9.86	
Oral speed reading	EG	11	48.40	30.19	
	CG	9	96.69	35.10	**0.008***
	Total	20	70.13	40.07	
RGDT/	EG	11	32.39	23.79	
RGDT-Exp	CG	9	13.00	3.50	**0.006***
(ms)	Total	20	23.66	20.02	

EG: experimental group; CG: control group; PST: phonologic awareness test; SAT: syntax awareness test; SPT: school performance test; RGDT: Random Gap Detection Test; RGDT-Exp: Random Gap Detection Test – Expanded; ms: milliseconds; *: statistically significant difference.

Discussion

The findings showed alterations in the bilateral perisylvian region (Figure 1) in most of the patients. Neuroimaging techniques (positron emission tomography and functional magnetic resonance imaging) in children with dyslexia showed a reduction in the activity of the left perisylvian region. Furthermore, there appears to be a structural and functional disconnection between the frontal and temporal language areas in dyslexic adults24.

According to Galaburda & Cestnick25, phonological dyslexia is related to difficulties in phonological processing, difficulty in reading irregular words and non- words, with more difficulty in non-words, and a deficit in verbal and nonverbal auditory processing. This is in agreement with the findings in this study. In addition, according to Galaburda & Cestnick, phonological dyslexia is related to damage in the superior temporal gyrus and temporoparietal region, consistent with areas affected by perisylvian polymicrogyia.

A deficit in phonological and syntactic awareness in children with dyslexia was observed in this study. These abilities are important in the recognition of syllables and words in reading since syntactic and phonological knowledge allow children to decode non-familiar words. The difficulties, associated with slower oral speed reading abilities, hinder the phoneme-grapheme identification, interfering in word recognition and reading comprehension19,22.

Children in the EG had a deficit in temporal auditory resolution. This study attributes this to an auditory processing disorder. Changes in temporal auditory processing make it more difficult to perceive subtle cues in speech resulting in difficulties in phonological processing, in agreement with the studies of Tallal13. However, not all children with dyslexia had auditory, visual or motor deficits. But these alterations, when present, should be considered risk factors for such disorders26.

Many researchers believe that there is a phonological deficit, but it may be secondary to a more general sensorimotor dysfunction. The difficulty in characterizing the origin of reading and writing disabilities is related to the fact that some tasks require different types of processing (phonological, auditory, visual and cognitive) that occur in a simultaneous and synchronized manner3,15.

Seven children had structural alterations in the perisylvian region and four children showed no lesions. According to Eckert27, different genes cause individuals with dyslexia to have different phonological processing deficits. The interaction of these genes may influence the anatomical and phenotypic variability of dyslexia.

Due to brain connections, affected areas may be a little more distant from the primary focus of the lesion, affecting several functions in different ways. Poldrack et al28 reported that regions such as the left inferior frontal cortex, involved in phonological processing, were also activated in temporal auditory processing tasks, suggesting that areas not typically considered auditory can play an important role in auditory processing, not to mention that phonological and auditory processing are closely related.

Conclusion

This study's findings suggest that school-age children with developmental dyslexia may show changes in temporal auditory processing with abnormal phonological processing. The data also showed that malformation of cortical development could be considered the anatomical substrate of these disorders.

Just as with language disorders, the structural and functional changes in cortico-subcortical regions are revealing for the study of the origins of dyslexia. However, not all children with dyslexia have brain injuries capable of being seen with current magnetic resonance techniques. With the advance of technology in neuroimaging and genetic studies it may become possible to understand different findings.

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