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Central auditory processing in children with dysphonia: behavioral and electrophysiological assessment

Processamento auditivo central em crianças com disfonia: avaliação comportamental e eletrofisiológica

Procesamiento auditivo central en niños com disfonía: evaluación comportamental y electrofisiológica

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Abstract

Introduction: Central auditory processing disorder may occur in parallel with other dysfunctions, such as dysphonia. **Objective**: To investigate auditory processing results in children with dysphonia. **Methods:** Comparative and cross-sectional study of 16 children aged 8 to 11 years old, who were divided into two groups: a study group of 7 children with functional or organic and functional dysphonia; and a control group of 9 children with no vocal complaints or disorders. After clinical assessment voices were recorded and children underwent perceptive voice evaluation, audiogram, and auditory processing with behavioral and electrophysiological tests. **Results:** A statistically significant difference was found between the groups with regard to dichotic nonverbal listening tests, humming in the frequency pattern test, and gap detection threshold, in addition to the percentage of correct answers in gap-in-noise test and for the P300 latency. **Conclusion:** Children with dysphonia had central auditory processing disorder

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Authors' contributions:
ABS: responsible for data collection, analysis of results and preparation of the article.
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with changes in listening skills for figure-ground to nonverbal sounds, ordering and temporal resolution and P300 latency suggesting a concomitant impairment in cognitive processing of acoustic information.

Keywords: Child; Hearing; Dysphonia; Auditory tests.

Resumo

Introdução: O transtorno do processamento auditivo central pode ocorrer em concomitância com outras alterações, assim como a disfonia. **Objetivo:** Analisar os resultados obtidos na avaliação do processamento auditivo central em crianças com disfonia. **Método:** Estudo comparativo e de coorte transversal, constituído por 16 crianças de oito a 11 anos reunidas em dois grupos: o Grupo Estudo composto por sete crianças com disfonia funcional ou organofuncional, e o Grupo Controle por nove crianças sem queixas e alterações vocais. Foram realizados os seguintes procedimentos: anamnese, gravação vocal, avaliação perceptivo-auditiva da voz, laringoscopia, avaliação audiológica básica, avaliação do processamento auditivo por meio de testes comportamentais e eletrofisiológicos. **Resultados:** Houve diferença estatisticamente significativa entre os grupos para as etapas de atenção direcionada no teste Dicótico não verbal, etapa de *humming* no Padrão de frequência, limiar de detecção de gap e porcentagem de acertos no *Gaps in Noise* e para a latência do P300. **Conclusão:** A partir da análise dos resultados verificou-se que o grupo com disfonia apresentou transtorno do processamento auditivo central com alteração nas habilidades auditivas de figura-fundo para sons não verbais, ordenação e resolução temporal e latência do P300 prolongada, sugerindo também um déficit no processamento cognitivo da informação acústica.

Palavras-chave: Criança; Audição; Disfonia; Testes auditivos.

Resumen

Introducción: El trastorno de procesamiento auditivo central puede estar en comorbilidad con otras alteraciones como la disfonía. **Objetivo:** Analizar los resultados obtenidos en la evaluación del procesamiento auditivo central en niños con disfonía. **Métodos:** Estudio comparativo y de corte transversal, constituido por 16 niños entre 8 y 11 años de edad reunidos en dos grupos: el Grupo de Estudio compuesto por siete niños con disfonía funcional u orgánico funcional y el Grupo Control compuesto por nueve niños sin quejas ni alteraciones vocales. Fueron realizados los siguientes procedimientos: Anamnesis, grabación vocal, evaluación perceptivo auditiva de la voz, laringoscopia, evaluación audiológica básica, evaluación del procesamiento auditivo por medio de tests comportamentales y electrofisiológicos. **Resultados:** Hubo diferencia estadísticamente significativa entre los grupos para las etapas de atención direccionada en el test Dicótico no verbal, etapa de *humming* en el Patrón de frecuencia, limiar de detección de gap y porcentaje de aciertos en el *Gaps in Noise* y para la latencia del P300. **Conclusión:** A partir del análisis de los resultados se verificó que el grupo con disfonía presentó trastorno de procesamiento auditivo central con alteración en las habilidades auditivas de figura-fondo para los sonidos no verbales, ordenamiento, resolución temporal y latencia del P300 prolongada; sugiriendo también un déficit en el procesamiento cognitivo de la información acústica.

Palabras claves: Niños; Audición; Disfonía; Tests Auditivos.

Introduction

Central auditory processing can be understood as the bridge that transforms the acoustic signal into functionally useful information. The condition known as Central Auditory Processing Disorder (CAPD) is identified when there is a limitation in the transmission, analysis, organization, transformation, elaboration, storage and/or retrieval and use of the information contained in the acoustic event[1].

CAPD may be associated with several changes, mainly related to human communication disorders: altered phonological system, dysphonia, and issues associated with fluency, speech, reading and writing, among others[2].

Dysphonia is a disorder that affects oral production and may have an incidence of up to 38% in the pediatric population[3]. However, being little perceived by children and little valued by parents and educators, the actual incidence of dysphonia in this population is still controversial[4,5].

Usually, when dysphonia is based on behavioral changes, patients have a distorted image of their own voice and rarely use their own auditory perception to control vocal production. Therefore, the auditory control system is essential in human vocalization, contributing for good vocal performance. The assessment of the hearing abilities of the dysphonic individual is important in order to establish therapeutic goals in vocal rehabilitation[6].

Dysphonia may have a negative impact on a child's overall health and affect the development of proper communication skills. Therefore, further research is required to investigate the relationship between dysphonia and central auditory processing in the pediatric population.

This study aimed to analyze the results of central auditory processing of dysphonic children through behavioral and electrophysiological tests considering both ears and to compare with the results of children with no vocal complaints or disorders.

Methods

This was a comparative and cross-sectional study approved by the Research Ethics Committee of the institution under no. 696.430/2014.

The study included 16 children, between eight and 11 years old, divided into two groups:

1) Study Group (SG) consisting of seven children diagnosed with functional or organic and functional dysphonia.
2) Control Group (CG) consisting of nine children with no vocal complaints and with auditory-perceptual assessment of the voice indicating normal variability in vocal quality.

Children who were included in the SG were referred from the Voice Outpatient Clinic of the institution (a sort of screening outpatient clinic) and underwent an otorhinolaryngological assessment prior to the auditory processing assessment.

The following criteria were adopted as inclusion criteria for both groups: results within normal levels in the audiological evaluation and in the Brainstem Auditory Evoked Potential (BAEP) with click stimulus, no other speech-language complaints, disorders of the auditory system, neurological disorders or cognitive deficits and the consent of the parents/guardians through the signature of the Informed Consent Form (ICF). The SG also included the diagnosis of functional or organic and functional dysphonia, the otorhinolaryngological evaluation (anamnesis and physical examination through laryngoscopy); while the CG includes those with no complaints and changes in vocal quality, as confirmed by the auditory-perceptual evaluation of the voices.

Data collection was performed in two consecutive days: the anamnesis, voice recording, audiological evaluation and part of the behavioral evaluation of auditory processing were performed on the first day. In turn, the second day included the completion of the behavioral evaluation and the electrophysiological assessment.

Procedures were performed as described

Anamnesis

The anamnesis was performed with the caregiver through the recording of identification data and the clinical history of the child in order to collect information on the child's overall, auditory, vocal and school development.

Voice recording and auditory-perceptual analysis

Voice recording of all subjects was performed according to the ASHA protocol, the Consensus Auditory-Perceptual Evaluation of Voice (CAPE-V)[7], which consists of the sustained emission of the vowel /a/ from 3 to 5 seconds, six predefined sentences and connected speech (spontaneous speech and counting numbers from 1 to 10). Voice samples were recorded in a Redusom acoustic booth, with a Shure SM58 microphone, M-Audio MobilePre USB sound card and a LG laptop using the Audacity software. The child was placed sitting down, with his/her feet on the ground and a unidirectional microphone positioned 10cm from the mouth.

The requested tasks were stored in different files and PRAAT software was used to edit voice samples, removing the beginning and end of the sustained vowel samples in order to obtain the most stable segments of voice productions. The speech samples were sent by e-mail with the adapted protocol and instructions to three speech-pathologists that blindly performed the auditory-perceptual evaluation.

Voice samples were analyzed using cut-off values of the visual analog scale with a metric from 0 to 100 millimeters (mm) according to the auditory-perceptual analysis of the overall degree of vocal deviation. Scores from 0 to 35.5 mm corresponded to the normal variability in vocal quality; from 35.6 mm to 50.5 mm were consistent with mild to moderate dysphonia; from 50.6 mm to 90.5 mm were considered as moderate dysphonia and from 90.6 mm to 100 as severe dysphonia[8].

The Cronbach's Alpha statistical test was applied in order to check the agreement between the three evaluators, obtaining an over 0.7 (minimum acceptable value) alpha coefficient for each task, which indicates a statistically acceptable internal consistency between the three evaluators. The general degrees of vocal change in each of the requested tasks were considered to perform the test.

The findings in the otorhinolaryngological evaluations were used to verify the presence of organic changes.

Audiological evaluation

All children were submitted to meatoscopy to ensure there was no conductive obstruction to perform the audiological evaluation.

The audiological evaluation consisted of pure-tone threshold audiometry, Logoaudiometry (Speech Reception Threshold [SRT] and Percentage Index of Speech Recognition [PISR]) and Tympanometry (Tympanometry and analysis of acoustic reflexes). Audiometry and logoaudiometry (hands-free) were performed in a Redusom acoustic booth using the Interacoustics AC40 Audiometer, TDH 49 supra-aural headphones, and tympanometry testing was performed using the Interacoustics AT 235H.

Behavioral Assessment of CAP

The study applied several tests, such as the Sound localization test, Memory tests for verbal and non-verbal sounds in a sequence, Dichotic digit test, Non-verbal dichotic test (free attention and listening directed to the right and left), Pediatric/Synthetic Sentence Identification Test-Competing Message, as adopted by Pereira and Schochat[9]; in addition to Frequency pattern (naming and humming) and Gaps-in-Noise (GIN) tests developed by Musiek[10,11].

For the sound localization test, the individual was required to locate the sound source (bell) considering front, back, above, right and left as possible directions. The child should have four or five correct directions, provided the right and left were correctly identified.

The memory test for verbal and non-verbal sounds in sequence consisted of syllabic verbal stimuli and non-verbal sounds produced by sound sources in three different sequences. The child was expected to have two or three correct sequences when asked to repeat the syllables and identify the objects in the order in which they were presented.

The Synthetic Sentence Identification Test-Competing Message consisted of the presentation of ten synthetic sentences with a contralateral competitive message (CCM) in the signal-to-noise ratio of 0 and -40 and ipsilateral competitive message (ICM) in the signal-to-noise ratio of 0, -10 and -15. Patients were asked to point out the sentence they heard that was written on a board. The pediatric sentence identification test was applied to 8-year-old children who were developing reading and writing skills. In these cases, children should point out the image corresponding to the sentence they heard. Ten children performed the synthetic sentence test, while six children performed the pediatric sentence test.

The dichotic digit test consists of different stimuli (two-syllable digits in Portuguese) that are simultaneously produced in both ears. This test can be applied in the binaural integration task, in which the subject is asked to repeat the four digits produced in both ears, and in the directed attention task, in which the individual listens to four digits simultaneously produced in both ears and must repeat only the one in the right or left ear. This study chose to apply only the binaural integration task.

Different non-verbal stimuli are produced simultaneously to both ears in the non-verbal dichotic test, and the patient is asked to pay attention to a non-verbal sound, ignoring the sound in the opposite ear and pointing to the figure corresponding to the sound in a board. The test was divided into three stages: free attention (FA), directed attention to the right (DAR) and directed attention to the left (DAL). The sounds produced represent a dog barking, a cat meowing, a rooster crowing, a door slamming, the church bell ringing and the sound of rain. A list of 24 pairs was presented in each stage, inverting the head phones after the first 12 pairs. In the FA stage, the child was asked to point out only the sound perceived with most ease after simultaneous stimuli. In the DAR stage, the child was asked to point out only the sounds heard in the RE; while in the DAL the child was asked to point out the sounds heard in the LE.

The frequency pattern test (as proposed by Musiek) consists of 60 presentations, being 30 in each ear (monaural), with low (880 Hz) and high (1122 Hz) pure tones, lasting 150 ms and with intervals of 200 ms between tones and 10 ms between sequences. The tones were produced in groups of three in six possible sequences (HHL, HLH, HLL, LLH, LHL and LHH). The patient was asked to name and then to vocally reproduce the tonal patterns heard (humming/murmuring). In the naming stage, “low” referred to 880 Hz tones and “high” to 1122 Hz tones.

The GIN test consists on the determination of the shortest time interval that can be detected in a continuous white noise. The gaps were randomly distributed in lists, and the different gap durations, from 2 to 20 ms, occur six times in each list. The subject was asked to indicate whenever a gap was noticed. The test was applied in the monoaural condition using different lists for each ear. The gap detection threshold (the shorted gap noticed by the patient in at least 66.6% of the times it was presented, that is, four times out of six) and the percentage of correct answers per test range (how many gaps were noticed in total) were calculated. The study by Amaral and Colella-Santos was used to interpret the results, in which the following values were found: 6.1 ms for the gap detection threshold, and 60% for the percentage of correct answers, based on the 95% confidence interval criterion as the cut off to normal range[12].

The behavioral assessment of auditory processing was performed in a Redusom acoustic booth using the Interacoustics AC40 Audiometer, TDH 49 supra-aural headphones, a laptop connected to the audiometer and a CD containing the tests recorded in Portuguese.

Electrophysiological evaluation of CAP

The BAEP was performed in order to assess the integrity of the auditory pathways to the brainstem, allowing the visualization and analysis of the absolute latency times of waves I, III and V and interpeaks I-III, III-V and I-V.

The P300-long-latency potential was performed to evaluate the activities in the areas involved in the auditory processing, such as the thalamus and cortex.

The two tests were carried out in a room with acoustic and electrical insulation, with low luminosity, using the Interacoustics Eclipse EP25 evoked potential device connected to the Positivo computer with EarTone insert headphones and eartips and Meditrace disposable electrodes. Subjects were placed in a reclining chair, their skin was cleaned with abrasive paste (Nuprep) and the electrodes were placed in accordance with the International Electrode System 10-20 standard, with the active (Fz) and ground wire (Fpz) on the forehead and the reference on the left (M1) and right (M2) mastoids. The electrodes were connected to the preamplifier and electrical impedance was maintained below 5KΩ, as recommended by the manufacturer.

The protocol used to obtain the BAEP included the monoaural production of 2000 click stimuli in rarefied polarity, a 19 clicks/second rate, an intensity of 80 dBNA, high-pass filters at 30 Hz and low-pass at 1500 Hz and a 15 ms analysis[13]. Two series of 2000 stimuli were recorded to verify the reproducibility of the waves and confirm the results.

Parameters for the P300 stimulus and acquisition were: oddball paradigm, monoaural production of 300 toneburst stimuli in rarefied polarity, a 1.1 second production rate, an intensity of 70 dBHL, high-pass filter at 1Hz and low pass filter at 30 Hz and the 750 ms analysis window. Frequent stimulus was produced at 1000 Hz, while rare stimulus was produced at 2000 Hz. Of the 300 stimuli produced, 20% refer to the rare stimulus and 80% to the frequent stimulus[14].

Statistical analysis

The results obtained in the evaluations were analyzed statistically. The descriptive statistics of the variables, with mean values, standard deviation, minimum and maximum values and p-values, were calculated to describe the sample profile. Fisher's exact test was used to compare gender between groups, while Mann-Whitney test was used to compare age and other numerical variables. ANOVA was used to compare test results between groups and ears for repeated measurements and data was transformed into ranks. A significance level of 5% ($p<0.05$) was adopted for all analyzes.

Results

The SG consisted of seven children with dysphonia, aged between eight and 10 years (average of nine years old), five boys and two girls. On the other hand, the CG consisted of nine children aged 8 to 11 years (average of 10.2 years old), five girls and four boys.

The otorhinolaryngological evaluation of the SG participants found that four children had functional dysphonia and three had organic and functional dysphonia.

Patient demographics (age and gender), as well as the overall severity of vocal deviation and laryngoscopy findings of the subjects included in the SG are shown in Chart 1.

Chart 1. Demographic characteristics of the subjects included in the SG regarding age, gender, overall severity of vocal deviation and findings in laryngoscopy.

Identification	Age*	Gender	Overall severity of vocal deviation	Findings Laryngoscopy
1	8	M	Mild to moderate	Nodule
2	8	F	Moderate	Posterior triangular glottic chink, sulcus and vasculodysgenesis
3	9	M	Mild to moderate	Median-posterior glottic chink
4	10	M	Normal variability	Nodule, median-posterior triangular glottic chink
5	10	F	Mild to moderate	Median-posterior glottic chink, edema and cyst
6	8	M	Normal variability	Nodule
7	10	M	Mild to moderate	Fusiform glottic chink

Legend: SG = Study Group; Age* = Age in years; M = male; F = female.

No statistical difference was found between the groups for sound localization, memory for verbal and non-verbal sounds in sequence, monotic for identification of synthetic or pediatric sentences and BAEP.

The performances of both groups for non-verbal and digit dichotic tests are shown in Table 1. A significant difference was found in the directed attention stage of the non-verbal dichotic test.

As shown in Table 2, a significant difference between the groups was found for the humming stage in the right ear in the frequency pattern test. Table 2 also shows the statistical difference between the groups for the GIN test.

In turn, Table 3 shows the results obtained in P300 for both groups, including a statistically significant difference for the measurement of latency in both ears.

Table 1. Performance of the SG and CG in the non-verbal dichotic test according to the number of correct answers and in the dichotic digit test in percentage of correct answers, considering right and left ear.

	SG				CG					
Tests	**Average**	**Min**	**Max**	**SD**	**Average**	**Min**	**Max**	**SD**	**p-value side and group**	**p-value SGXCG**
NVDT - FA									0.8575	0.4168
RE	12.3	8.0	15.0	2.5	12.7	11.0	15.0	1.2		
LE	11.3	8.0	14.0	2.2	11.3	9.0	13.0	1.2		
NVDT - DAR									ø	**0.0420***
RE	20.0	6.0	24.0	6.4	23.8	23.0	24.0	0.4		
NVDT – DAL										**0.0160***
LE	20.4	14.0	24.0	4.3	24.0	24.0	24.0	0.0		
DDT									0.5334	0.1195
RE	90.7	75.0	100.0	10.4	98.3	95.0	100.0	1.8		
LE	83.2	57.5	100.0	18.0	96.1	87.5	100.0	3.8		

Legend: NVDT = Non-verbal Dichotic Test; FA = Free Attention; DAR = Directed Attention to the Right; DAL = Directed Attention to the Left; DDT = Dichotic Digit Test. ANOVA for repeated measurements.

Table 2. Performance of the SG and CG in the frequency pattern test in naming and humming according to the percentage of correct answers, and in the GIN test in the percentage of correct answers and threshold in milliseconds, considering right and left ear.

	SG				CG					
Tests	**Average**	**Min**	**Max**	**SD**	**Average**	**Min**	**Max**	**SD**	**p-value side and group**	**p-value SGXCG**
FPT – N									0.5654	0.1949
RE	34.3	6.0	86.0	28.2	54.4	20.0	96.0	26.9		
LE	33.3	6.0	69.0	24.5	48.9	6.0	90.0	27.2		
FPT – H										**0.0158***
RE	55.4	13.0	100.0	32.1	94.0	46.0	100.0	18.0	**0.0367***	
LE	60.9	16.0	100.0	36.5	84.2	16.0	100.0	29.8		
GIN – CA									0.7474	**0.0045***
RE	49.7	30.0	76.0	15.7	72.8	46.0	96.0	16.0		
LE	47.4	35.0	63.0	9.8	66.1	43.0	94.0	14.2		
GIN - T									0.6869	**0.0023***
RE	8.7	4.0	15.0	3.7	4.7	2.0	8.0	2.1		
LE	8.4	5.0	10.0	2.1	5.3	2.0	8.0	1.9		

Legend: FPT = Frequency Pattern Test; N = Naming; H = Humming; GIN = Gaps-in-Noise; CA = Correct Answers; T = Threshold; ms - milliseconds; ANOVA for repeated measurements.

Table 3. P300 latency in milliseconds and amplitude in microvolts for the SG and GC, considering right and left ear.

	SG				CG					
Measurement	**Average**	**Min**	**Max**	**SD**	**Average**	**Min**	**Max**	**SD**	**p-value side and group**	**p-value SGXCG**
Latency									0.3923	**0.0382***
RE	372.9	292.0	448.0	47.7	325.1	284.0	366.0	30.3		
LE	357.4	300.0	426.0	44.9	328.2	262.0	356.0	28.2		
Amplitude									0.8714	0.46618
RE	5,449	0,000	12,430	3,875	6,482	1,681	10,640	2,870		
LE	4,388	0,240	6,803	2,204	5,985	0,081	11,730	3,683		

Legend: μV= microvolts. ANOVA for repeated measurements.

Discussion

As reported in the studies by Buosi et al (2013) and Ramos et al (2017), central auditory processing disorder may occur simultaneously with other changes, such as dysphonia; however, the relationship between these disorders remains unclear[15,16].

This study evaluated groups homogeneous with respect to gender and heterogeneous for age.

Regarding the distribution in each group, the Study Group (Table 1) that consisted of seven children, had a greater number of male subjects (five) than females (two). Despite the higher prevalence of dysphonia in boys already reported in the literature, there are no important anatomical-physiological differences in larynges between male and female subjects in childhood. Therefore, the higher occurrence of dysphonia and vocal nodule in boys can be explained by personality characteristics and inappropriate vocal behaviors, as observed in physical, playful and social activities (recreation, singing, among others), which require excessive use of voice. The average age of the SG is also similar to the age with the highest occurrence of dysphonia in the pediatric population[4,5,17].

As for the results obtained in the behavioral evaluation of the CAP, the performance of the SG in the non-verbal dichotic test (Table 1) was worse for directed attention tasks to both sides (right and left). Cavadas and Neves *et al*, also found changes in the evaluation of dysphonic children in this test[18,19]. This test allows the evaluation of the selective attention mechanism in a binaural separation task, attributed to the figure-ground ability for non-verbal sounds. The directed listening stages of the test investigate the integrity in the associative centers of the left hemisphere and/or corpus callosum when the stimulus is produced to the right ear, and in the right hemisphere, when the stimulus is produced to the left ear[9]. Changes in this test indicate a non-verbal gnostic impairment; that is, a prosody and intonation impairment that might be present in children with dysphonia.

Temporal ordering is assessed in the frequency pattern test, which allows the listener to extract and use prosodic aspects of the speech, such as rhythm, tonality, accentuation, intonation, as well as a sequence of vowels and consonants[20]. This ability involves the action of the two hemispheres, connected by the corpus callosum and depends on several central auditory processes, such as recognition, inter-hemispheric transfer, linguistic skills, sequencing of linguistic elements and memory signs[21]. The imitation stage (humming) is less complex than the naming stage, so a better performance is expected in this stage. In this study, both groups had greater difficulty in performing the naming stage compared to the humming stage (Table 2). The difficulty showed in the naming stage is in line with the literature[22]. Although the groups performed better in the humming task than in the naming stage, the SG still faced difficulties to perform this task. There was a statistically significant difference in the comparison between ear and group at this stage, in which the right ear of the CG had a better performance than the right ear of the SG. There are no findings in the literature reporting an advantage between the ears for the frequency pattern test. However, data in this study supports an advantage between different samples, even with the age difference in the groups.

Therefore, the results indicate a change in the temporal ordering ability in the SG, which was already reported in previous studies and which is also associated to a non-verbal gnostic impairment[16]. Individuals with impaired recognition of temporal patterns may experience difficulty in distinguishing sound relations in suprasegmental traits of speech and also in perceiving the differences between acoustic characteristics of sounds that may impact on auditory voice monitoring, which is a determining factor for the onset of speech dysphonia[6]. Studies with dysphonic teachers reported that although there no statistical difference was found between the study and control group, the auditory perception was different for frequency, duration and intensity of the sound, being more accurate in the group without dysphonia[15].

In the GIN test, which evaluates the temporal resolution ability, the SG performed worse in the percentage of correct answers and in the gap threshold compared to the CG (Table 2). Santoro, Ribeiro and Mesquita[23] were the only authors to apply the GIN test in a dysphonic population, but no significant results were reported. Ribeiro *et al*[24], applied the RGDT test in dysphonic adults, which also assesses temporal resolution skills, and they found changes in 80% of the sample. Therefore, this study reports the presence of changes in the temporal resolution skills in the dysphonic group.

Temporal auditory aspects are the basis of auditory processing and are also closely related to speech perception and its suprasegmental traits (prosody, voice quality and fluency)[25].

The electrophysiological evaluation is considered an important tool due to its objective character in the assessment of the structural and functional integrity of the CANS, as it does not require verbal responses and can also be used in the monitoring and evolution of cognitive disorders[26,27]. This is the first study to report the results of electrophysiological tests in a dysphonic pediatric population.

There was a significant difference between the groups for P300 latency (Table 3), with children with dysphonia having increased values in latency time when compared to the control group. On the other hand, there was no difference for amplitude, which is little studied due to its variability and for not having a well-established normality criteria[28]. Changes in this potential suggest impairments in the auditory cortex related to cognitive processing skills, such as memory, attention and auditory discrimination[27]. Thus, increased latency or decreased P300 amplitude are signs of a deficit in the cognitive processing of sensory information.

Although the individuals evaluated in this study were undergoing maturation of central auditory pathways, the significant delay in the P300 latency in the dysphonic group suggests a different auditory processing in comparison to the control group and a delayed conduction in cognitive processing of auditory information.

There was no statistically significant difference for the BAEP absolute and interpeak latencies, which are in line with the normality pattern reported in the literature, thus indicating the integrity of the auditory pathways to the brainstem in both groups[28].

The use of objective methods to assess hearing associated with behavioral methods contributes to increase the accuracy in the diagnosis of hearing disorders. Thus, when associating the findings of the two evaluations, this study found differences between the groups for the non-verbal dichotic and P300 tests, which allow assessing the attention to a non-verbal auditory stimulus. In the literature, studies report changes in attention in children with dysphonia[17,18]. Temporal processing tests and the P300 also evaluate the auditory discrimination. In this way, data from behavioral and electrophysiological assessments complement each other.

The findings show that children with dysphonia had greater difficulty with auditory processing skills, such as figure-ground for non-verbal sounds, ordering and temporal resolution, and cognitive mechanisms used to process auditory information, when compared to children with no vocal changes. Therefore, the findings suggest dysfunctions in the brainstem, auditory cortex, hemispheres and inter-hemispheric transfer (corpus callosum) regions. It should be noted that significant results were found in test with non-verbal and non-linguistic stimuli and, therefore, are related to the suprasegmental traits of speech. Results were also significant in skills that are related to acoustic parameters of the voice, such as frequency and duration.

Self-perception and vocal psychodynamics are important factors in the therapeutic process and the auditory feedback may contribute to vocal self-monitoring, thus minimizing vocal abuse[29]. In addition, discrimination and auditory feedback have a role in vocal production and subjects who have issues in analyzing and discriminating vocal parameters will also have difficulty reproducing them[30]. Given the impact of auditory processing, Ramos et al highlight the importance of auditory cues in speech-language pathology therapy in order to facilitate vocal exercises, which should contribute to therapeutic advances[16]. Thus, the identification of a hearing impairment can contribute to the referral and therapeutic assistance in the rehabilitation of dysphonic individuals.

Due to the limited number of subjects, this study was not able to match age and sex but, this is the first study to associate behavioral and electrophysiological assessments to investigate auditory processing in dysphonic children. Further studies in larger populations are required to assist in the understanding and interpretation of the results found in the assessment of auditory processing in this population, which may have a significant impact on the outcome of the speech-language pathology therapy.

Conclusion

The children with dysphonia included in this study had central auditory processing disorder.

The results allowed concluding that dysphonic children had changes in the auditory abilities of figure-ground for non-verbal sounds, ordering and temporal resolution when compared to the children of the control group. The study group also had increased P300 latency, suggesting impairment in the cognitive processing of acoustic information. There was no difference in the analysis between the ears.

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