CoDAS
ISSN 2317-1782 (Online version)

Artigo Original
Original Article

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The impact of vocal tuning in the perceptual auditory judgment of normal and deviated voice qualities

O impacto da afinação vocal na análise perceptivo-auditiva de vozes normais e alteradas

Keywords

Music
Auditory perception
Hearing tests
Vocal training
Screening
Voice

ABSTRACT

Purpose: To evaluate the ability that in tune and out of tune individuals have to identify normal and deviated voice qualities and to compare it with their performance in auditory processing tests and perceptual judgment. **Method:** The study investigated 15 in tune and 15 out of tune individuals. Participants were matched for age and sex, were amateur choir singers, had normal hearing thresholds and normal vocal quality. All individuals underwent Pitch-matching scanning to be classified as in or out of tune. Next, they performed the Pitch Pattern Sequence (PPS) and the Duration Pattern Sequence (DPS) tests and the perceptual judgment of 36 voices plus 20% of repetition for reliability analysis. **Results:** The out of tune individuals had worse performance in the PPS and DPS for both ears (p=0.002 RE; p=0.001 LE; p=0.009 DPS); no difference was observed in the perceptual judgment and the reliability (p=0.153). However, participants with normal PPS and DPS had better performance in the perceptual judgment and better reliability (p=0.033). Thus, individuals with disorders in temporal auditory processing skills have greater difficulty in the perceptual judgment and have lower intra-rater reliability, despite being in or out of tune. **Conclusion:** It can be observed that voice tone is not required to guarantee good perceptual judgment. However, temporal patterns and intra-rater reliability are essential to perceptually assess normal and altered voice qualities. Therefore, auditory training should be included in programs that aim to develop voice perceptual judgment abilities.

Descritores

Música
Percepção auditiva
Testes auditivos
Treinamento da voz
Triagem
Voz

RESUMO

Objetivo: Avaliar a habilidade de identificação de vozes normais e alteradas por indivíduos afinados e desafinados, comparando seu desempenho nos testes de processamento auditivo e na avaliação perceptivo-auditiva. **Método:** Participaram 15 indivíduos afinados e 15 desafinados pareados quanto à idade e sexo, oriundos de um coral amador, com limiares auditivos e qualidade vocal dentro dos padrões de normalidade. Todos foram submetidos à Triagem da Afinação vocal para a alocação nos grupos de afinados e desafinados. Em seguida, realizaram o Teste Padrão de Frequência (TPF), Teste Padrão de Duração (TPD) e análise perceptivo-auditiva de 36 vozes, mais 20% de repetição para teste de confiabilidade. **Resultados:** Os indivíduos desafinados apresentaram resultados estatisticamente menores que os afinados no TPF e no TPD para ambas as orelhas (p=0,002 OD; p=0,001 OE; p=0,009 TPD). Resultados da análise perceptivo-auditiva e da confiabilidade não apresentaram diferença (p=0,153). Contudo, esses resultados foram melhores quando comparados os participantes com valores normais no TPF e TPD, em relação aos resultados alterados (p=0,033). Assim, participantes com testes temporais de processamento auditivo alterados apresentaram maiores dificuldades na análise perceptivo-auditiva e menor confiabilidade intrassujeito, independentemente de serem ou não afinados. **Conclusão:** Percebe-se que a afinação vocal não é um pré-requisito para a realização de uma boa avaliação perceptivo-auditiva da voz, mas os padrões temporais e a confiabilidade intrassujeito estão notavelmente associados à análise perceptivo-auditiva de vozes normais e alteradas. Assim, sugere-se que o treinamento auditivo seja contemplado em programas de desenvolvimento da habilidade de realizar avaliação perceptivo-auditiva da voz.

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Received: May 27, 2019.

Accepted: September 17, 2019.

Study conducted at the Centro de Estudos da Voz – CEV, com base na experiência clínica dos autores.
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Conflict of interest: Nothing to declare.
Financial support: Nothing to declare.

INTRODUCTION

Vocal tuning is a state of perfect agreement between all the notes produced by the human voice[1]. Tuning implies reproducing the pitches of isolated notes and understanding the musical structure in which they are found, and may be influenced from an acoustic and cultural point of view[2]. Detuning is defined as the vocal reproduction of a melodic line that is different from the suggested interval between the notes model. Some presumed causes of vocal detuning are presented in the literature: psychological and attitudinal, neurological, cognitive, audiological, laryngological, respiratory, genetic, muscular, articular, perception, processing and memory difficulties, problems with auditory and proprioceptive feedback; in addition to internal self-reference to understand, process and remember musical material, lack of previous learning, cultural difference, among others[3]. For good listening reproduction, in addition to good hearing detection, efficient sensory processing is required[4].

It is known that vocal reproduction is also influenced by the processing of auditory information[5], which, in turn, relies on the efficiency and effectiveness of the central nervous system for the perception and use of auditory information. Auditory processing consists of a series of processes that occur over time and allow an individual to perform acoustic and metacognitive analysis of sounds, relating the skills involved in decoding, organizing and coding auditory sensory information, leading to the perception and understanding of sound information by the individual[6]. In it is inserted the auditory temporal processing, which concerns the perception of sound or its alteration within a limited time domain. It is a component present in most of the features of auditory processing, as many characteristics including sound information are somehow influenced by time. Thus, temporal auditory processing is considered a fundamental skill in the auditory perception of verbal and non-verbal sounds, in the perception of music, rhythm and punctuation, in the discrimination of frequency of duration and phonemes.

Among the abilities of temporal auditory processing is ordering, which involves the perception and processing of two or more auditory stimuli in their order of occurrence over time[7]. The ordering can be analyzed by the behavioral frequency pattern test (FPT) and by the duration pattern test (DPT), both of which also show a significant relationship between auditory processing and the individual's vocal tuning[8]. Be performance in the ability of temporal ordering and processing of auditory information concerning frequency is better in tuned individuals than in out of tune individuals[5].

The auditory-perceptual assessment is traditionally used in the clinical routine and is considered a gold standard method in the vocal assessment[9]. Its use is very important since the mobilization of the patient for treatment, in most cases, is the vocal complaint and the impact it causes on himself and others, that is, the perceptual changes in vocal quality[10].

The strategies used in the auditory-perceptual evaluation, mainly for clinical use, involve the comparison of voices to a system of personal references of the evaluator. Such an internal reference system is fluctuating and unstable and may cause variations in assessments[11].

Given the aspects underlying vocal tuning, temporal auditory processing and auditory-perceptual assessment of the voice, this research aims to assess the ability to identify normal and altered voices by tuned and out of tune individuals, comparing the performance of tuned and out of tune in auditory processing tests and auditory-perceptual assessment.

METHOD

The research was approved by the Research Ethics Committee under report number 2.501.293. Regarding its objectives, methods, risks and benefits, all participants who agreed to participate in the study were explained by signing the informed consent form.

This is a cross-sectional study that evaluated the process of identifying normal and altered voices carried out by 15 adult Brazilian individuals in tune and 15 out of tune, matched for age and sex (50% men and 50% women), aged between 29 and 59 years old ($\dot{X}$ = 44 years old), participating in an amateur choir for a year and a half, on average.

Initially, 32 choristers were invited to participate in an amateur choir that has been performing philanthropic presentations for 15 years and has a dynamic cohort of members entering and leaving.

The inclusion criteria of the sample consisted of the absence of vocal and audiological complaints, voice assessment and hearing within normal standards. Individuals with psychiatric, neurological and/or endocrine complaints were discarded. Therefore, for the selection of participants, all volunteers answered a demographic questionnaire and, if they met the inclusion criteria, they underwent audiological evaluation and vocal screening, screening of vocal tuning[12] and auditory processing temporal tests. Finally, they performed the auditory-perceptual analysis of a bank of 30 voices from the Centro de Estudos da Voz (CEV).

Clinical characterization questionnaire

To contemplate selection requirements for the population sample, the volunteers answered a questionnaire with data related to age, occupation, general health and specific questions about the presence or absence of vocal and/or auditory complaints, laryngeal symptoms, endocrine and/or neurological disorders, in addition to exposure to training and musical activities (singing, musical instrument, music education).

Audiological evaluation

For the audiological evaluation, the following materials were used: acoustic booth, Heine otoscope, Madsen audiometer model Itera II (frequency range 125-12500 Hz), with TDH 39P headphones, B71 bone vibrator, Madsen middle ear analyzer Zodiac 901 model with 226 Hz probe frequency.

Tonal audiometry evaluated frequencies from 250 to 8,000 Hz. Hearing thresholds up to 25 dB were considered normal at frequencies from 250 to 8,000 Hz. In meatoscopy and immittance testing, type A tympanogram and the presence of acoustic reflexes between 70 and 90 dBNS were considered within normal standards.

One participant was excluded for having altered audiological thresholds and tympanometry with type A curve, compatible with a moderate sensorineural hearing loss. At this point, the study sample was made up of 31 choristers.

Vocal screening

The vocal screening was performed through the auditory-perceptual analysis. Therefore, in a quiet environment, the participant was instructed to inspire and, shortly after, produce the following speech samples: 1. Sustained vowel "e", in usual and comfortable frequency and intensity; 2. Vowel "e" in low intensity, strong intensity and glissando for evaluation of the dynamic field; 3. Counting numbers from 1 to 20, in usual frequency, intensity and rhythm; and, finally, 4. Reading the CAPE-V sentences.

The auditory-perceptual analysis was performed by a speech-language therapist specialized in voice using the GRBAS scale[13], in which "G" refers to the general degree of vocal deviation, "R" to roughness, "B" to breathiness, "A" to asthenia and "S" to tension; these parameters were scored on a 4-point Likert scale, namely: 0 = no vocal disorder, 1 = mild vocal disorder, 2 = moderate vocal disorder and 3 = severe vocal disorder. For reliability testing, 10% of voice samples were repeated. The value of intra-rater reliability was 1,000, which can be considered almost perfect, according to Landis and Koch (1977). Only one of the choristers was evaluated with moderate vocal alteration and, therefore, was excluded from the sample, which now has 30 participants.

Participants with auditory thresholds and vocal quality within the normal range were referred to the following assessments: pitch tuning, auditory processing and perceptual-auditory analysis of voices.

Vocal Tuning Screening

To make the composition of the tuned and out of tune groups, the individuals were individually submitted to the Vocal Tuning Screening instrument[12], in which sound stimuli were emitted in the field, with comfortable intensity and compatible with the male and female weave. The instrument consists of two tasks, which were performed by the researcher with the aid of a piano. In Task 1, the individuals heard five isolated musical tones (E, G#, F, B, D#) and reproduced them using the vocal imitation. In Task 2, the subjects listened to the five three-tone sequences (E A F#, G D# F, D G E, D F A, A# F# E) and played in the same way as instructed in Task 1, or that is, right after their presentation. The stimuli were presented only once or repeated when requested, and the reproductions were recorded on a portable computer for registration and subsequent conference if necessary. The score used was a minimum of 8 (80%) of correct answers among the 10 tasks presented by the screening instrument.

From these results, the participants were allocated to the groups of tuned and out of tune: In tune - 15 individuals, seven female and eight men, who passed the tuning screening; Out of tune - 15 individuals, eight women and seven men, who did not pass the tuning screening. There was no difference between groups for the gender variable (p=0.50).

Then, all participants, in tune and out of tune, performed the auditory-perceptual evaluation of 30 vocal samples from CEV voice bank, located in the city of São Paulo. This evaluation was carried out at the same meeting as the evaluations that preceded the selection and formation of the groups, or at a subsequent meeting.

Auditory Processing Assessment

All individuals (n=30) underwent auditory processing assessment concerning temporal ordering, using the Auditec Frequency Pattern Test (FPT) and Duration Pattern Test (DPT). FPT and DPT are tests developed by Musiek[14] to verify the ability of temporal ordering through the discrimination of sound patterns, considered a physiological mechanism of temporal processing.

For FPT, tones at low frequencies (B), around 880 Hz, and high (A), 1430 Hz, were presented with a duration of 500ms and intervals of 300ms between tones. The tones were displayed in groups of three, with six possible sequences (AAB, ABA, ABB, BAA, BAB and BBA), making a total of 30 stimuli. The presentation occurred monaurally in each ear, at a level of 50 dBNS. The normal standards for this test are equivalent to a minimum of 75% accuracy.

DPT is a test with an application similar to FPT, but with long (L) stimuli, with 500ms, and short (C), 250ms, with an interval of 300ms between tones, with a constant frequency in 1000 Hz, at 50 dBNS. 30 sequences of three stimuli were also presented, in six possibilities (LLCC, LCL, LCC, CLL, CLC and CCL). The normal responses were those with over 70% correct answers.

The temporal tests of auditory processing allow two types of responses: imitation, in which there is greater participation of the right hemisphere and nomination, with greater participation of the left hemisphere. Participants were instructed to respond initially by naming the sequence of tones heard using the terminology thin/thick or low/high for FPT and short/long for the DPT test. If the performance was below the normal range (75% for FPT and 70% for DPT), the imitation task (humming) was requested, and the sequence of tones heard should be reproduced vocally. The correctness criterion in the test did not demand the accurate reproduction of the note, but the ability to differentiate different patterns of frequency and duration of sounds.

Auditory-perceptual analysis

The participants analyzed 30 voices from the CEV voice bank, being 15 normal and 15 dysphonic voices. The bank was composed of male and female voices, of a sustained vowel, and counting of numbers and months of the year. 20% (n=6) of the total sample (n=30) of voices was repeated, for testing the internal reliability of the participants, making a total of 36 voices.

For the auditory-perceptual analysis, individuals were instructed to assess the general degree of vocal deviation, considering both the sustained vowel and the number count of the selected vocal samples, using a 4-point categorical scale: normal voice, a little changed, moderate and very changed.

Participants performed the analysis individually, in a quiet environment using a headset. One voice was presented at a

time and, only after the answer, another voice was presented for analysis. The stimulus was repeated whenever requested by the participant.

The responses of the participants were checked with a template, previously prepared by three voice specialists, Brazilian, with an average of 9 years of clinical experience. For that, the specialists used the parameter G - general degree of deviation - of the GRBAS scale. The median value was used to define the gauge of the general degree of vocal deviation. The Kappa Coefficient (Ck) and Fleiss Kappa Coefficient (Fk) tests, which measured intra- and inter-subject reliability, respectively, indicated that experts were reliable in preparing the template (Table 1).

Table 1. Reliability data from the 3 expert voice judges

Speech task	Kappa Coefficient	P-value	Fleiss Kappa Coefficient (Fk)	P-value
Months			0.5038	<0.001
AV1	0.6667	0.0038		
AV2	0.6667	0.0038		
AV3	1.000	0.0127		
Numbers			0.5788	<0.001
AV1	1.000	0.0127		
AV2	1.000	0.0012		
AV3	1.000	0.0127		
Cape-v			0.6386	<0.001
AV1	1.000	0.0127		
AV2	0.6875	0.0112		
AV3	1.000	0.0127		

Statistical analysis

The data were tabulated and analyzed using descriptive and inferential statistics, using the SPSS 25.0 software. A significance level of 5% was adopted for all inferential statistical analyzes.

The continuous quantitative variables, namely: Frequency Pattern Test, Duration Pattern Test, auditory-perceptual analysis and degree of perceptual-auditory analysis, were analyzed descriptively by calculating the mean, standard deviation, median, minimum and maximum. The nominal qualitative variables gender, classification of the Frequency Pattern Test and classification of the Duration Pattern Test were analyzed descriptively by frequency and percentage.

To compare the quantitative variables according to the two independent groups, the distribution of variables was analyzed using the Shapiro Wilk test. All obtained non-normal distribution. Thus, the non-parametric Mann-Whitney test was used to compare these variables between the two research groups. The association between groups and nominal qualitative variables was performed using Fisher's exact test.

RESULTS

32 choristers were evaluated and, after the exclusion criteria were used, 30 individuals remained in the sample, divided into two groups, in tune (n=15) and out of tune (n=15). Of these, nine tuned individuals and four out of tune showed results of FPT within normal standards in the right ear, eight tuned individuals and three out of tune showed results of FPT within normal standards in the left ear and six tuned and one tuneless showed normal DPT results.

Table 2 shows the number and percentage of those tuned and out of tune as to normal and altered results of FPT and DPT and respective p-values.

Table 2. Number and percentage of correct responses in time-tested auditory processing in tuned and out of tune

PA test	Tuned				Out of tune				p-value
	Normal		Altered		Normal		Altered		
	N	%	N	%	N	%	N	%	
FPT RE	9	60	6	40	4	26.67	11	73.33	0.070
FPT LE	8	53.33	7	46.67	3	20	12	80	0.064
FPT RE	6	40	9	60	1	6.67	14	93.33	0.040

*p<0.05 – Fisher's exact test
Captions: N = number; % = percentage; FPT = Frequency Pattern Test; DPT = Duration Pattern Test; RE = right ear; LE = left ear

The analysis of the data in Table 3 shows that the average result of all participants was 60.27% in the Frequency Pattern Test for the right ear and 58.80% for the left ear, and 48.72% in the Duration Pattern Test. The group of out of tune individuals presented statistically lower results than the group of tuning in the Frequency Pattern Test for direct (p=0.002) and left ear (p=0.001), and in the Duration Pattern Test (p=0.009). The p-value refers to the comparison between tuned and out of tune.

Table 3. Analysis of the correctness by the degree of deviation and the reliability of the auditory-perceptual analysis in the total group researched and in the division of the tuned and out of tune groups

Variable	Total			Tuned			Out of tune			p-value
	Average	SD	Median	Average	SD	Median	Average	SD	Median	
Normal voice	56.67	22.40	53.33	62.67	23.48	66.67	50.67	20.28	53.33	0.126
Slight deviation	30.00	23.34	20.00	30.67	24.92	20.00	29.33	22.51	20.00	0.930
Moderate deviation	42.67	25.04	40.00	44.00	28.49	40.00	41.33	22.00	40.00	0.748
Intense deviation	**81.33**	**25.69**	**90.00**	**90.67**	**14.86**	**100.00**	**72.00**	**30.98**	**80.00**	0.054
Total hits	**54.00**	**17.56**	**56.67**	**58.89**	**18.02**	**60.00**	**49.11**	**16.21**	**53.33**	0.169
Reliability	**76.77**	**13.21**	**67**	**78.95**	**13.13**	**83.00**	**74.58**	**13.79**	**67.00**	0.153

*p<0.05 – Mann-Whitney test.
Captions: SD = Standard Deviation ; FPT = Frequency Pattern Test; DPT = Duration Pattern Test; RE = right ear; LE = left ear

The analysis of Table 4 shows that the overall average of correct answers in the auditory-perceptual assessment considering all participants was 54%. There was a higher average of correct answers by participants for voices with intense deviation (81.33%), followed by normal voices (56.67%), voices with moderate deviation (42.67%) and mild deviation (30.00%) in the auditory-perceptual analysis. There was no difference in the average of correct answers in the group as a whole, nor in the group of individuals who were in tune and out of tune considering the degrees of deviation. The reliability of the assessment of individuals from both groups also did not show a statistical difference. It is noteworthy that the presented reliability refers to the participants' internal reliability, tested with the repetition of the samples. The reliability of the participants in this sample was above 70%.

Table 4. Analysis of the correctness by the degree of deviation and the reliability of the auditory-perceptual analysis in the total group researched and in the division of the tuned and out of tune groups

Variable	Total			Tuned			Out of tune			p-value
	Average	SD	Median	Average	SD	Median	Average	SD	Median	
Normal voice	56.67	22.40	53.33	62.67	23.48	66.67	50.67	20.28	53.33	0.126
Slight deviation	30.00	23.34	20.00	30.67	24.92	20.00	29.33	22.51	20.00	0.930
Moderate deviation	42.67	25.04	40.00	44.00	28.49	40.00	41.33	22.00	40.00	0.748
Intense deviation	81.33	25.69	90.00	90.67	14.86	100.00	72.00	30.98	80.00	0.054
Total hits	54.00	17.56	56.67	58.89	18.02	60.00	49.11	16.21	53.33	0.169
Reliability	76.77	13.21	67	78.95	13.13	83.00	74.58	13.79	67.00	0.153

*p<0.05 – Mann-Whitney test
Captions: SD = Standard Deviation

Although the mean of correct answers in the auditory-perceptual assessment between those who were tuned and out of tune was similar, when analyzing the temporal tests (Table 5), individuals with normal results specifically in the Frequency Pattern Test for the left ear had a significant percentage of correct answers. Individuals with normal results in temporal tests also showed greater reliability in the auditory-perceptual assessment.

Table 5. Porcentagem total de acertos e confiabilidade da análise perceptivo-auditiva dos indivíduos com resultados normal e alterado nos testes temporais

Variables	Normal			Altered			
	Average	SD	Median	Average	SD	Average	p-value
FPT RE	59.85	17.57	60	16.2	16.2	53	0.12
FPT LE	62.91	16.84	60	49.21	15.79	53	0.033*
DPT	61.43	24.49	63	52.04	14.39	55	0.213
FPT RE Reliability	85.92	14.85	83	69.76	14.85	67	0.001*
FPT LE Reliability	86.3	14.45	83	71.21	9.22	67	0.003*
DPT Reliability	90.43	13.07	100	72.61	10.64	67	0.003*

*p<0.05 – Mann-Whitney test
Captions: Captions: SD = Standard Deviation; FPT = Frequency Pattern Test; DPT = Duration Pattern Test; RE = right ear; LE = left ear

DISCUSSION

The literature presents ample details on vocal tuning through studies that point out its relationship with cultural aspects, musical perception, vocal domain[2], innate neural mechanisms[8], emotions[15]; besides, motor-auditory integration in the control of the modulated voice as a function of attention at the level of the cortex[16] and integrity of the auditory skills, which are important for the vocal monitoring to produce an adequate behavioral response to musical stimuli[5]. Bearing in mind that there is no definite consensus and perhaps because it respects this wide conceptual scope on vocal tuning, a value determined within a scale to classify tuned and out of tune has not yet been presented.

However, based on the vocal tuning screening instrument[12] proposed by Moreti et al., And strengthened by the results presented by the Tonal Reproduction Test[17], the present study considered as tuned choristers those who presented 80% of correct answers, or that is, up to two errors, among the 10 tasks presented. In this way, the 30 choristers were allocated in two groups, of tuned and out of tune, each with 15 participants. When the vocal tuning screening test[12] was proposed, the studied musicians presented a maximum of 3 errors, representing 81.3% of correct answers in the task of emitting isolated tones and, in the task of temporal ordering of three tones, they presented correct answers greater than 75%. With close values, the results of the Tonal Vocal Reproduction

Test indicated an average of 87.8% of tuned reproductions in non-dysphonic women and an average of 71.5% of tuned reproductions in dysphonic women[17].

Among the issues related to vocal tuning, there are auditory skills. For example, a satisfactory vocal reproduction of what we hear occurs through efficient sensory processing of auditory information by the central auditory system[5]. There is an important relationship between vocal production and temporal auditory functions[17], since out of tune presented greater changes in auditory processing capacity in discriminating sound patterns related to frequency and time when compared to tuned ones. The same can be seen in the present study, with the group of out of tune showing lower results than the group of tuning, both in the Frequency Pattern Test, for direct (p=0.002) and left ear (p=0.001), as in Duration Pattern Test (p=0.009). Thus, it is possible to corroborate the hypothesis that the performance is higher in the FPT in tuned singers(5). The statistically significant relationship between the FPT and DPT tests and the vocal detuning of individuals was also presented in a research that found a much higher proportion of altered individuals among the group of out of tune in the group of tuned[8]. This relationship between vocal production and auditory functions confirms the importance of considering aspects of temporal auditory processing in the training of vocal tuning. A high standard deviation was found, mainly in the group of out of tune, reinforcing a great variability in the responses in the temporal tests, a result that has already been found in another study[17]. The individual condition of each participant to perform the test may be a determining factor for these results. Attentional, psychological, emotional, physical conditions factors may vary among participants and may have influenced this variability in the results of temporal tests, increasing their standard deviation. Central auditory processing, in turn, involves several auditory skills, and the joint performance of these skills may or may not favor the compensatory strategies used to answer the auditory challenges of the tests. This variability between auditory profiles can justify the high standard deviation found. It should be noted that detuning can also occur due to problems of perception, processing, memory, language and/or production of the emission, and these problems may have causes of an organic, cognitive, functional, attitudinal nature or be related to the combination of these factors[18].

The concept of normal and altered voice is not yet consensual. Usually, an emission produced without discomfort by the speaker and of good quality for the listener is considered as a norm; on the other hand, an emission produced with a certain discomfort by the speaker and considered noisy by the listeners can characterize an alteration[10]. In this study, the participants were correct between 17% and 93% of the voices presented for auditory-perceptual analysis, with an average of 54%. There was no difference in the auditory-perceptual evaluation between tuned and out of tune. Therefore, it is suggested that the voice evaluation may need, in addition to the temporal resolution, other skills related to the perception of harmonic and disharmonic components, necessary for the perception of patterns that compete in the judgment of a voice as normal or altered. The evaluator's individual perception, among other issues, is also a very important point in the auditory-perceptual analysis, making the auditory judgment influenced by professional and personal experience[27].

The auditory-perceptual analysis in the vocal evaluation is a subjective evaluation that has as filters elements such as the auditory impression, socioeconomic and cultural aspects until the individual preferences of the evaluator, allowing the inference of anatomophysiological data and important information about the psychosocial aspects of the voice[19]. In the evaluation process, countless adjectives and methods are used to qualify and classify a voice, which can generate some confusion, with disagreements between the listeners and difficulties in reaching a consensus about the terminology and method[20]. The highest mean of correctness in the auditory-perceptual analysis of the voice found in this study was for much altered voices (81.33%), followed by normal voices (56.67%), voices with average alteration (42.67%) and little changed (30.00%). That is, the more altered the voice, the more easily it was perceived as altered. There was no statistical difference in the mean of the correct answers of individuals tuned and out of tune in the auditory-perceptual analysis for normal and altered voices of no degree, as well as in the reliability of the assessment of individuals in both groups. A different result was found in the literature, in which another study proposed that the ear seems to be more reliable for assessing normal voices, however, there are considerable individual differences in the analysis of altered voices[11]. Given the subjective character inherent to auditory-perceptual assessment, the divergence of these findings once again seems to reinforce the variability of existing criteria in this type of assessment. However, it is this same subjectivity and diversity of parameters of the auditory-perceptual assessment that meets the varied clinical demands, since subjectivity permeates the assessment that the patient performs on his voice, which is why he seeks speech-language therapy treatment.

It is also necessary to consider that the present research had participants without training for auditory-perceptual assessment of the voice. In a study that investigated the learning factor during auditory-perceptual analysis, the voice specialist was more prepared and more susceptible to using learning strategies to improve his performance during an auditory-perceptual task, even if unusual. Thus, it was observed that professional experience influences in a positive way, with training being important in the formation of a voice specialist[21]. It is also important to remind that the listening situation that involves the knowledge or not of the clinical context has a direct impact on the auditory-perceptual assessment of the intensity of the perceived vocal deviation[27].

In addition to the analysis of the results of the auditory-perceptual assessment carried out by the research participants, the results of those who obtained normal scores in the FPT and DPT regarding their number of correct answers and reliability in the perceptual-auditory assessment of the voice were analyzed. In this research, only the participants who presented normal results in the FPT (p=0.001) presented to the LE obtained more correct answers in the evaluation of the general degree of the voices presented.

The pattern recognition, identification and sequencing process occurs from ipsi-and contralateral auditory pathways of the stimulated ear to the two cortical hemispheres and corpus callosum[22]. It is known that the sound signal circuit in the central pathways presents in its physiology a crossing that occurs in the brainstem, the auditory information presented in the right ear is transmitted to the upper nerve centers, both through the ipsilateral and the contralateral bundles. This binaural representation allows the system to respond to the minimum differences in time and intensity that occur between the two ears. Thus, the information presented in the right ear may take a few milliseconds longer to reach the left cerebral hemisphere than to reach the same area on the right side[23].

There was no difference in the auditory-perceptual assessment between the investigated groups, which demonstrates the fact that being tuned or out of tune does not influence the ability to evaluate voices, but rather the consistency of the answers, which should be considered mainly in the selection of judges for auditory-perceptual assessment.

The reliability of auditory-perceptual voice assessments is a central issue in voice research. Intra and inter-subject variations in the evaluation of the same audible signal, or of different tasks of the same individual, challenge researchers in the search for a theoretical model. There is already a proposal for a model that attributes several sources, for example, the evaluator's previous experience and training, his preferences, aspects related to speech tasks (sustained emission, chained speech) and causal errors[24]. Regarding intra-rater reliability, regardless of the ear, the participants who obtained normal results in the FPT were more reliable. Participants with normal results in the Duration Pattern Test showed significantly greater reliability in the auditory-perceptual assessment than participants with altered results (p=0.003). Another study that described the results of an auditory-perceptual assessment, characterized intra-rater reliability as low for 40% of the judges[26]. A survey focusing on reliability found that more experienced listeners tend to be more consistent in their assessments than untrained evaluators[20]. Another study also found good intra- and inter-evaluators voice specialists with clinical experience[28]. The research proposes that hearing can and should be trained clinically, to improve the scores obtained in the evaluation[29,30]. The finding in the present study shows that possibly the greatest intra-subject reliability in the evaluators with normal FPT and DPT occurs because they perceive acoustic variations over time more systematically. Thus, the temporal pattern of the central auditory processing of the evaluators is an important parameter in the training of evaluators in the auditory-perceptual analysis of the voice, which also has an impact on increasing its reliability. Previous studies on perceptual auditory assessments of the voice have shown that the reliability of this analysis can also be increased by eliminating factors that influence the variability of the evaluator, using, for example, corresponding tasks, external synthetic anchors, sustained vowel stimuli and unidimensional classifications, in addition to validated and widely used protocols[25].

In this study, individuals with altered auditory processing time tests had greater difficulties in auditory-perceptual analysis and less intra-subject reliability in this task, regardless of whether they were tuned or not. When considering the development of the various professionals who work with the human voice, such as speech-language therapists, voice specialists, singing teachers, vocal scientists, vocal coaches, police officers and experts, although vocal tuning is not a prerequisite for the performance of a good auditory-perceptual assessment of the voice, the temporal patterns and intra-subject reliability are notably related to the auditory-perceptual assessment of normal and altered voices. In this way, it was possible to identify that the auditory ability to perceive the frequency patterns is directly related to the recognition of voices and offers subsidies to consider the importance of their training in the improvement of the auditory-perceptual assessment.

CONCLUSIONS

Vocal tuning is related to the temporal patterns of central auditory processing; however, it is not a prerequisite for performing a good auditory-perceptual assessment of the voice. However, temporal patterns and intra-subject reliability are notably related to the auditory-perceptual analysis of normal and altered voices. Thus, it is suggested that the auditory training of temporal patterns is part of programs to develop the ability to perform a perceptual-auditory evaluation of the voice.

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Authors' contributions

MT was responsible for the study conception, article design, collection, data tabulation, data analysis and writing of the article; IG was responsible for the study design, article design, data analysis, writing and critical review of the manuscript's intellectual content; GMVM was responsible for the study conception, article design, data analysis, writing and critical review of the manuscript's intellectual content; MSB was responsible for the coordination, proposal and conception of the study, article design, writing, article review and final approval.