Original Article

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Influence of auditory feedback in the vocal acoustic parameters of individuals without vocal complaints

Influência da retroalimentação auditiva nos parâmetros acústicos vocais de indivíduos sem queixas vocais

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ABSTRACT

Introduction: The quality of the vocal emission is dependent on the integrity of the auditory feedback mechanism of the presence of eventual failures is related to the induction of abuse and / or vocal misuse, and therefore of the surgeon of dysphonia. **Purpose:** To evaluate the influence of auditory feedback in voice intensity and frequency in individuals with no vocal complaints. **Methods:** Participants were 40 female subjects without vocal and auditory thresholds within normal standards complaints. Participants underwent an auditory evaluation composed of pure tone audiometry, tympanometry and a vocal acoustic assessment of intensity and frequency parameters, carried out in three stages: before, during and after exposure to white noise. **Results:** There was significant difference in the average of the ratio obtained in intensity and between the threshold of contralateral acoustic reflexes and vocal frequencies in the three moments of acoustic evaluation. **Conclusion:** Thus, the findings suggest that auditory feedback interferes with the control of the intensity and vocal frequency.

Keywords: Feedback; Auditory perception; Voice quality; Pitch discrimination; Loudness perception

RESUMO

Introdução: A qualidade da emissão vocal é dependente da integridade do mecanismo de retroalimentação auditiva. A presença de eventuais falhas nesse mecanismo está relacionada à indução do abuso e/ou mau uso vocal e, por conseguinte, do surgimento de quadros de disfonia. **Objetivo:** Avaliar a influência da retroalimentação auditiva na intensidade e na frequência da voz, em indivíduos sem queixas vocais. **Métodos:** Participaram da pesquisa 40 sujeitos do gênero feminino, sem queixas vocais e com limiares auditivos dentro dos padrões de normalidade. As participantes foram submetidas a uma avaliação auditiva, composta por audiometria tonal liminar, imitanciometria e por uma avaliação acústica vocal dos parâmetros de intensidade e frequência, realizada em três momentos: antes, durante e após a exposição ao ruído branco. **Resultados:** Houve diferença significativa na relação das médias obtidas na intensidade e entre o limiar dos reflexos acústicos contralaterais e as frequências vocais, nos três momentos da avaliação acústica. **Conclusão:** Os achados sugerem que a retroalimentação auditiva interfere no controle da intensidade e frequência vocal.

Palavras-chave: Retroalimentação; Percepção auditiva; Qualidade da voz; Nível de discriminação sonora; Percepção sonora

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INTRODUCTION

The human being's main and fundamental means of communication is the voice. Vocal quality (VQ) allows information to be expressed about physical and psychosocial characteristics, involving the speaker's singularity, personality and humor, configuring a set of characteristics that identify a voice[1].

For adequate control of the quality of vocal emission, the integrity of the auditory system is of primordial importance[1]. More specifically, the acoustic reflex is a mechanism with relevant participation in modulating vocal intensity, or at the beginning of vocalization[2,3]. Another important function of this reflex is its action in improving speech discrimination, particularly at high intensities and in frequency selectivity. In addition it provides improved auditory attention to continuous sounds and selectivity for the auditory signal, rather than the background noise[4], which suggests that the acoustic reflex has important functions in auditory feedback in environments with or without noise.

In the presence of eventual failures in the auditory feedback mechanism, it is very common to observe absence or insufficient regulation of the acoustic parameter of vocal intensity, inducing abuse and/or vocal misuse, and therefore leading to the appearance of conditions of dysphonia[5,6]. This situation is compatible with one of the etiologies of hoarseness in individuals, as well as frequent recurrence of these symptoms after treatment.

The changes in voice parameters observed during the discourse differ from those that occur during the voluntary act of "speaking loudly", such as, for example, when a speaker simply asks to speak more strongly, or when professors raise the intensity of their voice to make themselves understood by students in a large classroom. This finding emphasizes the Lombard effect, characterized by the increase in vocal amplitude in response to an increase in background noise, as a natural reflex, and it may be an indication that different mechanisms of neural control are involved in the voluntary and involuntary change in voice amplitude[7].

To have good VQ, efficient action of the auditory feedback system is necessary. Knowledge about its functionality is fundamental for the prevention of vocal pathologies, particularly in individuals who make use of their voice professionally, and who are exposed to noisy environments on a daily basis. Thus, the aim of this study was to investigate the way in which auditory feedback may influence the acoustic vocal parameters of individuals without vocal complaints, and without changes in the tonal auditory thresholds.

METHODS

This was a descriptive, analytical study conducted in a Speech Therapy Clinic-School in Salvador, Bahia, Brazil during the period from May to June 2014, approved by the Ethics Committee on Research with Human Beings, of the *Universidade do Estado da Bahia* (UNEB) under Protocol No. 467.932. All the subjects agreed to participate in the research and signed the Free and Informed Term of Consent.

The study sample, obtained by convenience sampling, was composed of 40 women, because the literature contained more reports of studies involving women[8,9] and it was easier to obtain volunteers. All subjects were adults without vocal complains and presented auditory thresholds within normal limits. Initially, the voice evaluation questionnaire[1] was applied to investigate the risk factors to which the participants were exposed, as well as their routine and general health conditions.

Afterwards, the auditory evaluations were made with the procedures of meatoscopy, tone threshold audiometry at frequencies from 250 Hz to 8000 Hz[10], as well as the Speech Recognition Threshold (SRT) and Speech Recognition Percentage Index (SRPI) using digital AC-30 Interacoustics® audiometry. Acoustic Immittance measurements were made by means of the middle ear analyzer - immittance audiometry AZ-7 Interacoustics®, for the purpose of verifying the tympanic-ossicular mobility and contralateral acoustic reflexes at the frequencies of 500 Hz, 1000 Hz, 2000 Hz and 4000 Hz.

The participants included in the study underwent a spectrographic voice evaluation, when they were asked for sustained emission of the vowel /a/, sequential speech (days of the week) and threaded speech (singing "Happy Birthday") [11]. For this evaluation, the following items of equipment were used: *Notebook Emachines* D442-V081, earphones with clone microphone and PRAAT software - vocal analyzer.

The samples were recorded in a specific vocal analysis program, PRAAT software, and subsequently submitted to spectrographic analysis to obtain the frequency (pitch) and intensity (loudness) measurements. The mean *pitch* and loudness measurements of each vocal sample provided in the icons "*voice reports*" and "*intensity*", respectively, both localized in the analysis window of PRAAT, were taken into consideration.

The participants' voices were recorded in three time intervals: before, during and after exposure to noise. In the second time interval they were exposed to white noise at an intensity of 80 dB NPS and duration of 100 seconds, by means of the earphones inserted in both ears.

The recordings were compared according to the following grouping: mean of the time interval before exposure and mean of the time interval during exposure; mean of the time interval before exposure compared with the mean of the post-exposure time interval. In addition the mean time intervals before and after exposure were compared with the contralateral acoustic reflexes evaluated. That is, for analysis of each group, the means of the mean pitch and loudness values of each vocal sample were obtained.

The statistical program SPSS, version 17.0., was used to perform the analyses. The paired t-test and Pearson Correlation tests were performed, considering the level of significance of 5% ($p \leq 0.05$).

RESULTS

The sample comprised 40 participants of the female gender, with a mean age of 26.6 (±8.5) years. The mean vocal frequency and intensity values of the three recording time intervals were calculated. Difference was observed between the mean intensity values in the time intervals before and during exposure, and before and after exposure to noise (Table 1).

When comparing the acoustic reflex responses with vocal emission values from the aspects of intensity and frequency before and after exposure to noise (Table 2), absence of correlation was observed between the acoustic reflexes, and difference in intensity was observed between the time intervals before and after exposure to noise. There was difference between the acoustic reflex thresholds and the different time intervals from the aspect of frequency, before and after exposure to noise, showing values at 1000 Hz (p=0.05 and r=0.53) and 2000 Hz (p=0.01 and r=0.85).

DISCUSSION

According to analysis of the results obtained in the research, difference was observed in the mean intensity measurements of the vocal samples obtained between the time intervals before and during exposure to noise, and the time intervals before and after exposure to noise. Furthermore, difference was observed between the correlation of the acoustic reflexes and vocal samples of the time intervals before and after exposure to noise.

The mean vocal intensity of 65.6 (±6.2) dB under habitual conditions was similar to the results of an investigation with 58 adult individuals, in whom the mean value of the time interval without exposure to noise was 63.8 dB for the female gender[12].

Under the condition of exposure to noise, it was possible to observe an increase in the mean intensity to 70.5 (±6.2) dB, making the sample statistically significant when compared with the mean intensity value obtained before exposure to noise. The findings in the specialized literature demonstrated a significant increase in intensity, with the increase in the level of masking noise, confirming the Lombard effect theory, in which the vocal intensity increased systematically with the increase in noise level[13].

After exposure to noise, the mean intensity value diminished in comparison with the time interval during exposure to noise, however it remained higher than the value before exposure. This fact is related to a normal process caused by the diminished sound perception, because time is necessary for vocal stabilization to occur, and this may vary from one individual to another. This result has been observed in the literature; this affirmed that the absence of auditory monitoring generated changes, mainly characterized by uncontrolled change in intensity and a shift in fundamental frequency[14].

Table 1. Comparison between the mean values and standard deviation, in the three different time intervals of vocal analyses

Loudness (dB) $\bar{X}$ (SD)			Pitch (Hz) $\bar{X}$ (SD)		
Before	Duration	After	Before	Duration	After
65.57 (6.24)	70.48 (6.19)	67.83 (6.55)	239.63 (107.20)	256.02 (85.18)	271.47 (111.55)
p≤0.001*		p=0.04*		p=0.56	p=0.17

*Significant values (p≤0.05) - Paired T-test
Subtitle: SD = standard deviation

Table 2. Distribution of results obtained by means of correlation between the acoustic reflexes and difference between the time before and after the voice recording

Acoustic reflexes (dB)			Correlation of acoustic reflexes with difference in loudness before/after ($\bar{X}$ = 1.80 ± 3.28 dB)				Correlation of acoustic reflexes with difference in pitch before/after ($\bar{X}$ = 45.87 ± 117.00 Hz)			
			Right ear		Left ear		Right ear		Left ear	
Frequencies (Hz)	Right ear	Left ear	p	r	p	r	p	r	p	r
500	98.42±8.34	99.74±7.54	0.39	0.22	0.22	-0.32	0.48	0.21	0.09	-0.49
1000	96.58±8.98	95.28±8.13	0.31	0.27	0.35	-0.29	0.05*	0.53	0.35	-0.30
2000	92.37±8.72	93.16±8.20	0.17	0.36	0.48	-0.19	≤0.01*	0.85	0.39	-0.26
4000	94.71±8.74	93.68±5.97	0.96	-0.01	0.28	-0.28	0.12	0.50	0.61	-0.15

*Significant values (p≤0.05) Pearson Correlation Coefficient
Subtitle: p = level of significance; r = level of correlation

Other researchers[15] have observed that the auditory vocal control system may be influenced by innate causes or individual differences, so that frequencies and intensities are controlled independently at neuronal level. There is also a hypothesis that the increase in intensity under masking noise conditions would be generated by a variety of strategies that may be physiologically differentiated among persons[13].

Relative to the aspects of frequency, the mean value of 239.6 Hz (±107.2) was found under the initial condition. On introducing noise, a mean value of 256.0 Hz (±85.2) was obtained. This rise had been estimated due to the condition of exposure. After the noise ceased, the mean frequency value was 271.5 Hz (±111.6). In this study, no difference was observed between the mean frequency values obtained when compared with the time intervals before and during exposure, and the time intervals before and after exposure to noise.

These results differed from a study about the analysis of vocal modifications in reporters in a situation of noise, conducted with 46 subjects, of whom 23 were reporters (Case Group) and 23 non-reporters (Control Group), in which the acoustic values of variability in frequency in Hz were higher in the presence of masking noise, because the increase in vocal intensity generated a shift in fundamental frequency, since both groups presented an increase in the mean intensity and frequency values when 50 dB and 90 dB of masking noise were inserted[16].

The duration of exposure to noise used for this study was approximately 2 minutes, and in this period it was already possible to observe the changes in the vocal aspects of intensity and frequency. When compared with the time of exposure to noise of workers who used their voice as their main instrument of work, and whose minimum hourly load was six to eight hours, it could be suggested that these physiological changes in frequency and intensity would occur to an even higher degree, leading to more intense effects.

In an investigation about the incidence of dysphonia in professors, a study verified that after using the voice for hours on end, vocal change, acoustically characterized by the spectrum with reduction in energy in the harmonic/noise ratio and changes in fundamental frequency could occur, in the same way as continuous exposure to noise for various hours would cause harm to the process of auditory feedback, leading to the individual having greater difficulty with controlling the vocal aspects after the noise ceased[17].

Furthermore, in this study we observed that there was statistically significant difference when the vocal aspect of intensity was evaluated alone, by only comparing the means among them. Whereas, when the vocal intensity values were correlated with the acoustic reflexes, there was no difference. To the contrary, when the aspect of frequency was evaluated alone, in spite of the fundamental frequency being higher after masking noise, no difference was verified. However, when correlated with the acoustic reflexes it was possible to observe difference.

Nevertheless, the authors could suggest that when the acoustic reflexes were correlated with the vocal samples from the aspect of intensity, the difference was justified by the participation of these reflexes in modulating the vocal intensity and in the frequency selectivity of speech.

In women, the vocal chords vibrate approximately 250 times per second to generate an enunciation. When the volume of the voice is systematically raised, phonatory overexertion is generated, which could cause vocal alteration. The literature[18] indicated that women are more predisposed to developing vocal fatigue, because the female voice has a higher fundamental frequency when compared with the male voice.

Auditory feedback is a system that auditorily monitors sequential speech, and for effective monitoring to occur, it is necessary to guarantee the integrity of the efferent auditory pathway, with the stapedian reflex response to strong sound intensity being one of the most evident, constant and stable responses among the efferent responses of the auditory pathway[19]. In addition to this function, this acoustic reflex is also responsible for the improvement in speech discrimination at strong intensities and in the selectivity of frequency, thus justifying the relationship between the acoustic reflex and difference in frequency before and after masking noise[20].

In this study, the authors were able to observe that the acoustic reflex thresholds found at the frequencies of 1000 Hz and 2000 Hz had a positive correlation with the thresholds before and after exposure to noise; that is, the higher the acoustic reflex threshold, the greater was the difference between the time interval before and after exposure to noise.

Another interesting observation of this study was with respect to the predilection of laterality, in which it was verified that the reflex responses obtained revealed significance only in the right ear in 50% of the frequencies evaluated. These findings were in agreement with the theory that the central and peripheral auditory systems function in a lateralized manner, in which the cochlear activity to the right is more significant than that to the left, however, with irregular predominance throughout the extension of the cochlear duct[21]. Clinical findings have pointed out the medial olivocochlear bundle (MOB) as a fundamental component in the maintenance of the pattern of peripheral asymmetry, with the modulation of cochlear function being mediated by the cortex through the efferent fibers[22].

Evidences of improved responses of the auditory evoked potentials of the brain stem, with greater amplitudes of wave III, as well as in the registers of signals from otoacoustic emissions in the right ear, as opposed to the greater prevalence of complaints of ringing (in the ears) and diagnosis of auditory loss in the left ear, confirm the theory of asymmetry between the ears, and suggest that the left ear is more susceptible to auditory changes, especially when exposed to occupational noise[23,24,25,26].

The dopaminergic neurons of MOC are almost exclusively observed in the basal or medial portion of the cochlea. In this region, there are indications of greater selective frequency modulation, especially in the range of 1-4 kHz, in which greater effect of contralateral suppression of acoustic stimulation was verified[27].

Therefore, the authors could suggest that there was greater probability of the occurrence of failure in auditory feedback for sound of medium frequency, which resulted in a significant increase in vocal frequency. In this sense, frequency-altered auditory feedback was classified as a variation, usually between 1/4 to 1/8 above or below, in the speaker's voice frequency. With this resource, the speaker hears his/her own voice at a frequency that differs from the usual one[28].

The afferent discharge from the sensory receptors in response to changes in condition of the larynx and vocal tract is transmitted to the brain stem, and then to the motor neurons of the larynx muscles. This intrinsic reflex system of the larynx may be particularly activated when auditory feedback has failed or has been interrupted[13].

Therefore, in the population with failure in the auditory feedback mechanism, there is an increase in mean fundamental frequency as a result of the absence of acoustic feedback, when it is common for more vocal effort to be produced by the speaker to make himself/herself understood during oral communication[29], which justified the findings of this research. On the other hand, in a study about the correlation between environmental noise in the classroom and the professor's voice, the hypothesis raised in many publications - that the presence of environmental noise would be related to the presence of changed voices among professors[30] - was not confirmed.

In view of the analyses performed, the authors could infer that the findings of this study were compatible with the findings in the literature, and could contribute to the development of studies with a preventive approach, in the sphere of vocal hygiene. In addition it could contribute to the study of treatment for VQ of individuals who make professional use of the voice, who are exposed to noisy environments on a daily basis, as well as those with auditory deficiency.

Moreover, continuity in defining normative values for different age groups and genders is still necessary for the purpose of suiting these values to clinical practice, such as improving understanding of this most complex relationship between voice and hearing.

CONCLUSION

The condition of exposure to masking noise caused an increase in the voice intensity of workers, and interruption of exposure to noise caused a reduction in vocal intensity. There was positive correlation between the acoustic reflexes and difference in frequency between the time intervals before and after exposure to masking noise.

Therefore, auditory feedback is fundamental in the control of vocal parameters. Moreover, auditory feedback training in persons with vocal changes may be necessary for the efficacy of treatment and prevention of vocal pathologies.

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