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Original Article

Acoustic voice analysis: effect of an audio-visual training for speech therapy undergraduates

Análise vocal acústica: efeito do treinamento auditivo-visual para graduandos de Fonoaudiologia

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ABSTRACT

Purpose: To verify the effectiveness of a training for acoustic voice assessment with undergraduate students of Speech-Language Pathology. **Methods:** Study conducted with 14 undergraduate students of Speech-Language Pathology who participated in six theoretical/practical weekly encounters, whose total duration was four hours and a half. Basic concepts of acoustic voice assessment was performed; we used spectrographic analysis to each parameter, visually and auditory. In order to verify the proposal's effectiveness, the undergraduate students assessed before and after de training, the measures of automatic extraction of the evaluation measures and also aspects of narrowband spectrograph of 15 voices, normal and disordered in varying degrees. We considered the performance of students, before and after the training comparing their mistakes and correct scores to a previous analysis performed by a specialist with Kappa index >0.70. To compare the results obtained by the undergraduate students in the two instances McNemar test was performed. **Results:** For all parameters analyzed the average of correct scores was higher after the training, as well as the overall average (24.2% before and 93.0% after). **Conclusion:** The developed training was effective for the learning of undergraduate students, and may be included into subjects which involve concepts of voice assessment and also might be transformed into teaching material available to other groups.

Keywords: Voice; Voice disorders; Speech acoustics; Sound spectrography; Observer variation; Training

RESUMO

Objetivo: Verificar a efetividade de treino para avaliação acústica da voz com graduandos de Fonoaudiologia. **Métodos:** Estudo realizado com 14 estudantes de curso de graduação em Fonoaudiologia, que participaram de seis encontros semanais teóricos e práticos, com duração total de quatro horas e meia. Foram abordados os conceitos básicos para avaliação vocal acústica perceptivo-auditiva e foi praticada a análise espectrográfica de cada parâmetro, visualmente e auditivamente. Para verificar a efetividade da proposta, os graduandos realizaram, antes e ao final do treino, a avaliação das medidas de extração automáticas e de aspectos da espectrografia de banda estreita de uma amostra de 15 vozes, normais e alteradas em variados graus. O desempenho dos alunos foi considerado nos dois momentos, comparando-se os erros e acertos em relação à análise prévia realizada por especialista, com índice Kappa >0,70. Para comparação entre os resultados obtidos pelos graduandos, nos dois momentos, utilizou-se o teste de McNemar. **Resultados:** Para todos os parâmetros analisados, as médias de acerto foram maiores no momento pós-treino, com maioria dos índices acima de 90%; o mesmo observou-se em relação à média geral (24,2% no momento pré-treino e 93,0% no momento pós-treino). **Conclusão:** O treino mostrou-se efetivo para a aprendizagem dos graduandos, podendo ser incorporado às disciplinas que envolvem os conceitos de avaliação da voz e transformado em material didático disponível para outros grupos

Descritores: Voz; Distúrbios da voz; Acústica da fala; Espectrografia do som; Variações dependentes do observador; Capacitação

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INTRODUCTION

From the fifties onwards there has been advancement within the field of vocal studies with the upcoming of theories focusing on vocal production and the development of voice laboratories devoted to creating reliable and objective technics that could contribute to the evaluation of vocal disorders(1). The current acoustic vocal analysis makes use of softwares that enable measurement of various aspects of the voice signal captured(2). The use of that analysis started three decades ago(3) and the current studies are the most comprehensive.

The acoustic analysis offers speech therapists and audiologists relevant data and it is a very important tool to the speech therapy evolution control, besides enabling the register of vocal conditions at the pre and post-period of laryngeal surgeries(4-6). It is through the acoustic analysis that diverse specific parameters which help the comprehension of the phonetic mechanism and the different vocal disorders are obtained and it also enables graphic visualization of aspects of a produced sound(7).

The multivariate analysis of acoustic vocal data has been ensuring a greater reliability of that evaluation(8) and the classification in types of the spectrographic signal has been proving itself relevant, especially for voices more altered in which the objective parameters, such as fundamental frequency and indexes of interference and noise, are less reliable(9).

Even though acoustic analysis has its advantages it does not have a diagnosis function. It is, however, part of the vocal evaluation along with the physiological tests findings performed by the doctor and the auditory-perceptive analysis of voice(7).

The acoustic evaluation provides interesting visual data which may be discussed with the patience in a way that facilitates the feedback over the treatment´s evolution(10). The difference between amplitude measurements of the two first harmonics (H1-H2) has also been subject of study in a way that relates it to vocal characteristics offering new analytical possibilities(11). The combination between the auditory-perceptive and the acoustic evaluation makes the identification of the diversions in the vocal quality easier and generates data that will serve as a foundation for the choice of therapy and vocal exercises proposed(10).

The acoustic analysis of vice provide normative data for different vocal realities even if the quantity of information to be extracted is little known and explored(12). The most used parameters are the objective measurements such as fundamental frequency and the interference indexes jitter e shimmer(13), noise measurement(14) and the aspects originated from the spectrography with the presence of noise in high frequencies, instability and sound breaks(15). The spectrography enables the visual monitoring of the vocal characteristics through its three-dimensional aspect (frequency/intensity/time)(5,16).

Even though the visual ability is the main one involved in the spectrographic analysis, it is desired, for this type of evaluation, that during the training both auditory and visual abilities should be worked on together in order to obtain the best apprenticeship, since some aspects will be better perceived visually as they would be auditory detected and vice versa. The visual aid of the spectrogram may help the auditory-perceptive evaluation of the vocal quality(13,17). As the spectrographic vocal analysis is a subjective method of evaluation for it depends on the evaluator its reliability may be enhanced when the training involves more than one ability(16,18).

The training for acoustic analysis focused on the spectrography proved to be relevant in study with 20 undergraduates of Speech-Language Pathology(16). This training lasted a total amount of four hours and the results found point to an improvement on the visual interpretation of spectrograms.

In order to perform the vocal acoustic analysis with effectiveness it is necessary that the evaluator gains experience and knowledge concerning the specific programs, recording resources, data base structuring and result analysis through graphic form, and beyond that the knowledge on the reference parameters. Therefor it is necessary that the graduation enhances the evaluator's ability for this type of analysis. The multi-dimension aspect of the voice should be explored during the graduation of the future speech therapists and audiologists with an integrated approach of signals, considering the necessary improvement of didactics tools.

The importance of investing in theoretical/practical abilities of the therapist students is, more and more, evident so that they would have a more complete graduation and would develop specific abilities that will allow them to care adequately for the dysphonic individuals' needs(19,20).

The objective of this research was to verify the effectiveness of the training on acoustic evaluation of voice for undergraduates of Speech-Language Pathology.

METHODS

It concerns a longitudinal study, approved by the Research Ethics Committee of the *Universidade de São Paulo* (USP), School of Medicine (CEP 294/11).

Inclusion criteria: undergraduates of the 2nd year of the Speech-Language Pathology Course without previous experience on vocal acoustic analysis. Exclusion criteria: absence at any proposed meeting.

The sample was composed of 14 students (12 women and 2 men, at the age between 19 and 24 years old, without auditory complaints) who fitted in this criteria and the research procedures started after signing the term of free and clarified consent.

The training on vocal acoustic evaluation program comprehended six weekly meetings totalizing four and half hours, split in three steps: Step 1, in which the definitions were introduced, parameters were trained and evaluation of the vocal registers sample performed (meeting 1); Step 2, in which the purpose was a reinforcement of each parameter´s concept separately (meetings 2, 3, 4 and 5); Step 3, in which a general review of all acoustic parameters took place and a reevaluation of the vocal registers samples were performed (meeting 6).

Step 1: at the first meeting, which lasted for one and a half hours, the following vocal acoustic analysis parameters were approached: automatic extraction measurements – fundamental frequency, jitter, shimmer and harmonic-noise proportion – spectrographic analysis of narrow band – spectrographic design form, darkening level of the harmonics, design stability, noise on the high frequencies, noise on the low frequencies, presence of sub-harmonics/bifurcations, frequency breaks, sonority breaks, series of harmonic analysis and harmonic definitions. Each aspect was approached, initially, by its definition and, afterwards, examples of spectrograms of narrow band were showed in a color version to make the reading easier. Visual aspects of the drawings were highlighted at the same time as auditory stimulus were present for the training of the respective parameter. The duration of the exposure of each resonant stimulus was three to five seconds and students required an average of three replays for each voice.

Each parameter altered/present was exhibited in opposition to a spectrogram in which showed normal/absent. In the Figures 1 and 2 we observe an example of the presentation of sub-harmonics.

The same dynamic of training took place for the automatic extraction measurements training. Measurements values were exhibited while the relating characteristics were identified on the spectrogram. For example, in the training for fundamental frequency (f0) analysis, the definition and the normative data related to gender and age were presented and, then, various spectrograms exhibited in which the harmonic characteristics in each stripe of frequency were pointed out while students listened to the voices. In relation to the other automatic extraction

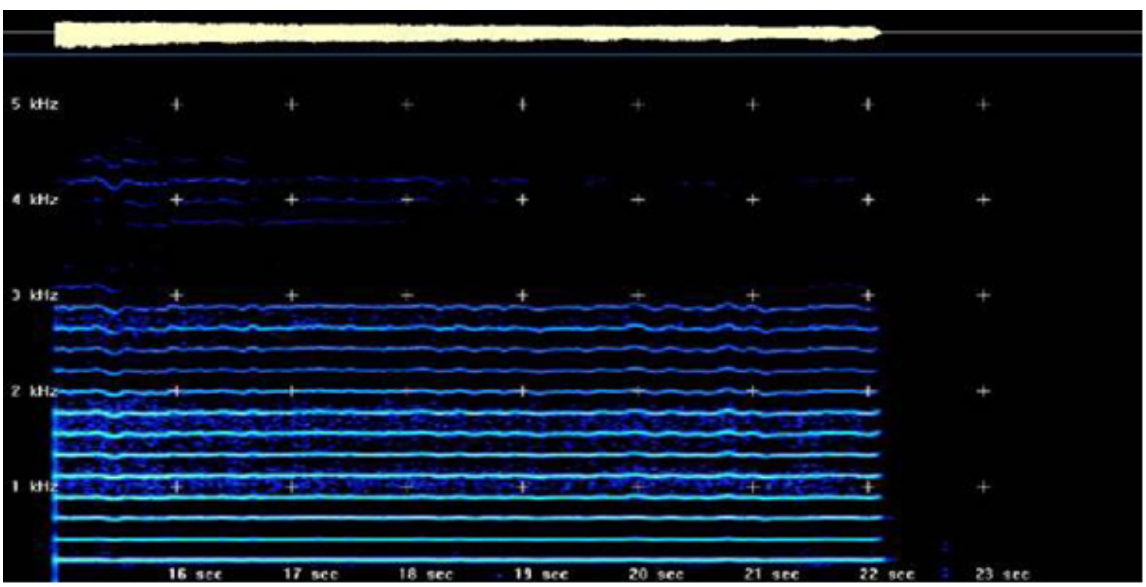

Figure 1. Regular spectrogram, with the presence of harmonics up to 3 KHz and without sub-harmonics presence

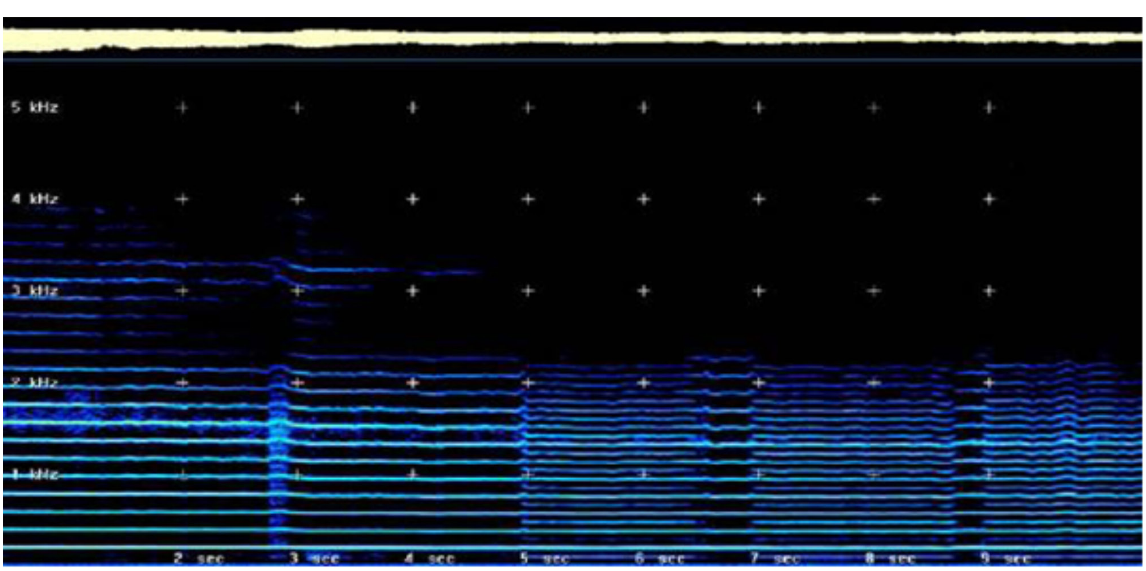

Figure 2. Spectrogram in which the presence of sub-harmincs presence is highlighted

measurements – jitter, shimmer and PHR – the parameters of normality and its meanings were discussed and spectrograms of voices presented together with the information about the different values for comparison with normal voices. The parameters for spectrographic analysis followed the operational definitions[15,21], taking into consideration the whole drawing and not only the f0, to know:

- Instability: excessive fluctuation in the frequency; frequency breaks: sudden alterations of frequency; sonority breaks: interruptions and/or sudden absence in the frequency; sub-harmonics/frequency bifurcation: presence of one or more lines between the harmonics; noise over the high frequencies: hatching on the frequencies above 4 Khz/5 Khz; noise over the low frequencies: hatching on the frequencies below 2 Khz; series of harmonics: sufficient number of harmonics for defining de vocal quality (minimum of 20 harmonics).

For the analysis of the defined parameters in this research an adaptation of the specific protocol[15] has been used. In that protocol an analogic-visual scale of 100 mm was used in which 0 (zero) indicates absence and 100 maximum presence in each of the parameters, except for the frequency breaks and sonority breaks analysis in which presence and absence is considered. For this research only presence and absence of each parameter was considered, something that it is more compatible with the level of requirement expected from the undergraduates.

At the end of the presentation of all aspects, during that same meeting, it was proposed that the students performed an evaluation of one sample of voices. A slide was presented for each voice with one spectrogram and the audio indicating, right under the spectrogram, measurements of automatic extraction (values of f0, jitter, shimmer and harmonic-noise proportion) that may be correct or not. The students listened to the voice while observing the spectrogram and the automatic measurements values. They were invited to take individual notes in writing, using a specific protocol, of the presence or absence of the required characteristic (for example: “point out if there is sonority break”) or if the automatic measurements values were compatible with the voice, justifying (for example: “the f0 value indicated is compatible with the pitch that you are hearing? Why?”). Connected to the projector there was portable notebook HP Pavilion dv6000, with a Intel® Core™2 Duo Processor T7250 (2 GHz, 2 MB L2 HD, 800 MHz FSB), 260 MB of RAM and sound board Realtek High Definition Audio; for the sound system it was used two external loudspeakers in order to ensure the quality of the sound stimulus presented.

For the extraction of automatic measurements the software PRAAT was used (developed by Paul Boersma and David Weenink from the University of Amsterdam, of free use, http://www.fon.hum.uva.nl/praat/) and for the elaboration of the spectrograms the Spectrogram, version 16 (developed by Richard Horne, Visualization Software LLC, of free use, http:/www.eletronics-lab.com/downloads/pc/003/).

The samples evaluated by the students were composed by nine voices of individuals with varied laryngeal diagnosis and one with a voice without alterations; five samples were repeated in order to enable the intra-judge evaluation. The recordings were selected from the voice database from the institution, under the responsibility of one of the authors. All patients selected went through the routine procedures for vocal registering in an acoustic treated environment and with noise inferior to 50 dB, to know: desktop computer, Audacity software, external sound board USB 5.1 eD (Interface Edirol UA-101 Hi-Speed USB Audio Capture), internal digital amplifier Class B from the brand 3D Sound, headset microphone unidirectional and condensed from the brand Karsect, model HT-2; the microphone was set at distance of 3 to 5 cm from the mouth of the patient in axis of 45° to 90º, there were tests performed for the setting of voice gaining with the objective of avoiding cuts of peaks or very low sounds. The samples were recorded at the frequency track of 22.050 Hz.

Step 2: after the first initial meeting, four weekly meetings took place, with a duration of 30 minutes each, in which were recaptured, in details, all acoustic parameters approached and evaluated during the first meeting; new examples were used for visual and auditory training, with circa three voices presented for each item discussed.

Step 3: at the sixth meeting a general review of all the worked on acoustic parameters was included and, afterwards, the students repeated the evaluation of the voices from the initial sample following the same procedures described. The order of presentation of the voices at this second instance has its random sequence modified in relation to the first evaluation. It is important to highlight that none of the voices of the evaluation sample was used during the training meetings.

The evaluations performed by the students at the two instances were compared to the previously evaluation done through the GRBAS[22] scale by three female judges, speech therapists and audiologists specialized in voice and with an extensive experience in the use of the referred scale. All the participant judges presented Kappa index above 0.70 at the intra-judge analysis. One of the evaluators was also responsible for the extraction of automatic measurements using the software PRAAT, as well as for the spectrographic data analysis. That comparative analysis permitted the students’ responses to be classified into correct and error scores and enabled a comparison performance of the two instances through the application of the McNemar test, adopting level of significance of 5%.

The adopted criteria for the selection of voices were: varied laryngeal diagnosis and graduations of vocal quality alterations (Chart 1). All vocal registers presented one or more parameters of interest worked on during the training.

Complete program of the training:

Step 1: 1º meeting – basic concepts for vocal evaluation followed by individual evaluation of 15 voice samples (Instance 1); duration of one and half hours.

Step 2: 2º meeting – theory and practice for analysis of the spectrographic drawing form, level of harmonics darkening and

Chart 1. Characterization of the selected voice sample for acoustic evaluation

Individuals	G	R	B	A	S	Otorhinolaryngological diagnoses
1	3	2	3	1	0	Trachea trauma
2	3	3	1	0	0	Reappearence reinke´s edema
3	2	2	1	0	1	Reinke´s edema
4	3	3	1	0	1	Reinke´s edema
5	2	2	1	0	1	Parkinson´s disease
6	2	2	2	0	1	Laryngeal papilloma
7	0	0	0	0	0	Normal
8	3	3	2	1	0	Direct vocal cords paralysis
9	3	3	1	0	2	Laryngeal stenosis with synechia
10	2	2	1	0	0	Presbyphonia

Note: GRBAS = G, general degree; R roughness; B, breathiness; A, asthenia; S, strain

design stability, duration of 30 minutes; 3º meeting – theory and practice for analysis of noise presence, sub-harmonics/bifurcation e frequency breaks; duration of 30 minutes; 4º meeting – theory and practice for sonority breaks analysis, harmonic series and harmonic definition; duration of 30 minutes; 5º meeting – theory and practice for fundamental frequency analysis and of interference jitter measurement, duration of 30 minutes.

Step 3: 6º meeting – theory and practice for interference shimmer measurement analysis and of noise measurement proportion harmonic-noise followed by brief theoretical/practical review of all concepts and parameters worked on during the meetings; after that, all participants reevaluated, individually, the same 15 voices from the initial evaluation through the same procedures (Instance 2); duration of 30 minutes.

RESULTS

At Instance 1 high indexes of correct scores for fundamental frequency were observed (55.0%), drawing stability (47.1%) and drawing form (42.1%). The lower indexes happened towards (2.0%), noise on the high frequencies (3.6%) and frequency breaks (11.4%). The general average of correct scores was 24.2% (Table 1).

At Instance 2 all of the correct scores indexes were very high, in which the jitter analysis (99.3%) and fundamental frequency (97.9%) standing out; the lowest average obtained was for sub-harmonic/bifurcations presence (82.9%). The average of correct scores was 93.0% (Table 1).

The comparison of the students' performance indicated that there has been higher index of correct scores at Instance 2 in relation to Instance 1 on all of the aspects analyzed (p>0.001) and also on the average of correct scores (p>0.001). The highest differences, pre and post-training, were observed in the noise evaluation on the high frequencies, noise on the low frequencies, frequency breaks, harmonics and harmonics definition series (Table 1).

DISCUSSION

Acoustic analysis is considered an important

Table 1. Comparison between average of correct scoresat the two instances of the evaluation

Analyzed aspects	Instance 1		Instance 2		p-value
	n	%	n	%	
Fundamental frequency	77	55.0	137	97.9	<0.001*
Jitter	39	27.9	139	99.3	<0.001*
Shimmer	41	29.3	134	95.7	<0.001*
Harmonic-noise proportion	39	27.9	136	97.1	<0.001*
Drawing form	59	42.1	128	91.4	<0.001*
Harmonic darkening level	32	22.9	127	90.7	<0.001*
Drawing stability	66	47.1	136	97.1	<0.001*
High frequencies noise	5	3.6	128	91.4	<0.001*
Low frequencies noise	21	15.0	133	95.0	<0.001*
Sub-harmonics/bifurcations	30	21.4	116	82.9	<0.001*
Frequency breaks	16	11.4	129	92.1	<0.001*
Sonoroty Breaks	25	17.9	127	90.7	<0.001*
Harmonics series	22	15.7	135	96.4	<0.001*
Harmonics definition	2	2.0	83	84.7	<0.001*
General average	33.9	24.2	12.7	93.0	<0.001*

*Significant values (p≤0.05) – McNemar test complementary tool for vocal evaluation and theoretical/practical knowledge is necessary for the speech therapy/audiology practice[1,20,23]. So in order to obtain correct scores full results it is necessary for the professional to develop specific abilities[20]. Such consideration is corroborated in this study for it was possible to observe that, with only one initial class in which the aspects were conceptualized and exemplified in a more general form, that students showed an output that varied from weak to regular and, only after the training, effectively started to perform consistent acoustic analysis with high average of correct scores.

It is important to emphasize that the students that took part at this present study didn´t have any previous experience with acoustic analysis, however, in the prior semester, they had taken part in the training for perceptive-auditory voice analysis, which was considered effective[24].

After the mentioned training, students started improving their perception for multi-dimension aspect of voice and the previous knowledge on perceptive-auditory analysis may have contributed for their comprehension of how the acoustic signal validates the perceptive-auditory signal and vice versa, apart from allowing a integration of physiological and perceptive-auditory spheres[25].

The fact that students showed a certain easiness to evaluate the fundamental frequency, form stability and spectrographic drawing, based only on the concepts studied during the first lesson of the basic level, could be justified by the fact that they were more simple parameters. The study that involved visual inspection of spectrographic drawing showed the students' easiness in analyzing the drawing form[16] may indicate that the learning of this parameter does not depend on the contribution of the visual and auditory analysis training.

On the other hand, the initial difficulty in identifying the presence of noise on the high and low frequencies, as well as the frequency breaks, made it possible to indicate that they are aspects which need longer time of training to be perceived more adequately. Study in which the proposal was only visual inspection of the spectrographic drawing, students had difficulty to evaluate the presence of noise based on a brief explanation, even though the evaluation of this aspect has grown worse after the training[16], which is something that proves itself to be a more complex parameter. Besides that, analysis that involves auditory and visual aspects may confuse, a little, students at the beginning, probably because of the higher quantity of information, but it could be overcome with the training as observed in this research. According to experienced judges the association of perceptive-auditory and acoustic aspects improves the reliability of the analysis[18].

The improvement on the harmonics definition analysis observed in this research shows that the integration perceptive-auditory-visual benefits the students, once the study, only with visual support, observed difficulty of the undergraduates in relation to this parameter[16]. The more direct way of the automatic measurements analysis – jitter, shimmer and PHR – resulted in high indexes of correct scores by students after the training. That result was expected because it is more objective and simple to verify the value presented by the program and to compare it to the normality data, even if during the Step 1 students seemed confused because of the complexity of these items definition. The need of comprehension of the short period measurements is highlighted by the fact that the interference measurements – jitter and shimmer – as much as the noise measurements are considered strong indicators of vocal problems[26].

As the acoustic analysis, in general, aggregates relative subjective characteristics to the interpretation of data by the evaluator[16], it would not be expected at the post-training instance that indexes reached were 100%. The indexes were considered excellent and corroborated for the effectiveness of the training.

The systematization at various meetings has been evaluated as adequate for the appropriation of knowledge and the expansion of the concepts range presented and acquired. The possibility of content reviews at each meeting allowed time for reflection and doubt clarification, as well as extra training observations, which can contribute for the absorbing and sedimentation of knowledge. It is believed that this learning experience has contributed for those students' abilities in performing a more complete vocal evaluation, once they had been through the perceptive-auditory training[24], and now have aggregated acoustic knowledge. The next challenge is an integration between the perceptive-auditory, acoustic signals and the voice disorders' physiology involved. It is also the intention, from this study, to make the didactic material used available to undergraduates.

It is important to highlight the limited amount of studies on that theme and also its relevance for the undergraduates of Speech-Language Pathology. This research points out to the need of permanent reflection over didactic practices and the learning process of the student, especially on complex themes such as voice evaluation. Making the didactic material of well succeeded experiences available should be reinforced and publicizing in events of the field will allow other groups to have access to the same methodology, which will make researches inter-institutions feasible.

CONCLUSION

Training for voice acoustic evaluation for undergraduates of Speech-Language Pathology proved to be effective for the learning process. The best results were obtained at the post-training instance.

REFERENCES

1. Zitta SM. Análise perceptivo-auditiva e acústica em mulheres com nódulos vocais [dissertação]. Curitiba: Centro Federal de Educação Tecnológica do Paraná; 2005.

2. Vieira VP, Biase NG, Pontes P. Análise acústica e perceptivo-auditiva versus coaptação glótica em alteração estrutural mínima. Acta AWHO. 2005;23(1):6-12.
3. Pontes PAL, Vieira VP, Gonçalves MIR, Pontes AAL. Características das vozes roucas, ásperas e normais: análise acústica espectrográfica comparativa. Rev Bras Otorrinolaringol. 2002;68(2):182-8. http://dx.doi.org/10.1590/S0034-72992002000200005
4. Kelchner LN, Brehm SB, Weinrich B, Middendorf J, Alarcon A, Levin L et al. Perceptual evaluation of severe pediatric voice disorders: rater reliability using the consensus auditory perceptual evaluation of voice. J Voice. 2010;24(4):441-9. http://dx.doi.org/10.1016/j.jvoice.2008.09.00
5. Cortês MG, Gama ACC. Análise visual de parâmetros espectrográficos pré e pós-fonoterapia para disfonias. Rev Soc Bras Fonoaudiol. 2010;15(2):243-9. http://dx.doi.org/10.1590/S1516-80342010000200016
6. Hosokawa K, Ogawa M, Hashimoto M, Inohara H. Statistical analysis of the reliability of acoustic and electroglottographic perturbation parameters for the detection of vocal roughness. J Voice. 2013;28(2):263.e9-16. http://dx.doi.org/10.1016/j.jvoice.2013.07.005
7. Nemr K, Amar A, Abrahão M, Leite GCA, Köhle J, Santos AO et al. Análise comparativa entre avaliação fonoaudiológica perceptivo-auditiva, análise acústica e laringoscopias indiretas para avaliação vocal em população com queixa vocal. Rev Bras Otorrinolaringol. 2005;71(1):13-7. http://dx.doi.org/10.1590/S0034-72992005000100003
8. Reynolds V, Buckland A, Bailey J, Lipscombe J, Nathan E, Vijayasekaran S et al. Objective assessment of pediatric voice disorders with the Acoustic Voice Quality Index. J Voice. 2012;26(5):672e1-7. http://dx.doi.org/10.1016/j.jvoice.2012.02.002
9. Fouquet ML, Behlau M, Gonçalves AJ. Uma nova proposta de avaliação do segmento faringoesofágico e sua relação com a espectrografia acústica na voz traqueoesofágica. CoDAS. 2013;25(6):557-65. http://dx.doi.org/10.1590/S2317-17822013.05000010
10. Lundström E, Hammarberg B. Speech and voice after laryngectomy: perceptual and acoustical analyses of tracheoesophageal speech related to voice handicap index. Folia Phoniatr Logop. 2011;63(2):98-108. http://dx.doi.org/10.1159/000319740
11. Cordeiro GF, Cunha MGB, Menezes MHM, Ubrig-Zancanella MT, Nemr K. Discriminação entre vozes adaptadas, levemente soprosas e tensas: diferenças entre os dois primeiros harmônicos. Rev Soc Bras Fonoaudiol. 2010;15(2):238-42. http://dx.doi.org/10.1590/S1516-80342010000200015
12. Finger LS, Cielo CA, Schwarz K. Medidas vocais acústicas de mulheres sem queixas de voz e com laringe normal. Braz J Otorhinolaryngol. 2009;75(3):432-40. http://dx.doi.org/10.1590/S1808-86942009000300020
13. Laureano JM, Sá MFS, Ferriani RA, Romao GS. Variations of jitter and shimmer among women in menacme and postmenopausal women. J Voice. 2009;23(6):687-9. http://dx.doi.org/10.1016/j.jvoice.2008.04.005
14. Godino-Llorente JI, Osma-Ruiz V, Sáenz-Lechón N, Gómez-Vilda P, Blanco-Velasco M, Cruz-Roldán F. The efectiveness of the glottal to noise excitation ratio for the screening of voice disorders. J Voice. 2010;24(1):47-56. http://dx.doi.org/10.1016/j.jvoice.2008.04.006
15. Leão SHS. Análise espectrográfica acústica de vozes rugosas, soprosas e tensas [dissertação]. São Paulo: Universidade Federal de São Paulo; 2008.
16. Valentim AF, Cortes MG, Gama ACC. Análise espectrográfica da voz: efeito do treinamento visual na confiabilidade da avaliação. Rev Soc Bras Fonoaudiol. 2010;15(3):335-42. http://dx.doi.org/10.1590/S1516-80342010000300005
17. Martens JW, Versnel H, Dejonckere PH. The effect of visible speech in the perceptual rating of pathological voices. Arch Otolaryngol Head Neck Surg. 2007;133(2):178-85. http://dx.doi.org/10.1001/archotol.133.2.178
18. Camargo Z. Análise da qualidade vocal de um grupo de indivíduos disfônicos: uma abordagem interpretativa e integrada de dados da natureza acústica, perceptiva e eletroglotográfica [tese]. São Paulo: Pontifícia Universidade Católica de São Paulo; 2002.
19. Fukuyama EE. Análise acústica da voz captada na faringe próximo à fonte glótica através de microfone acoplado ao fibrolaringoscópio. Rev Bras Otorrinolaringol. 2001;67(6):776-86. http://dx.doi.org/10.1590/S0034-72992001000600005
20. Menezes LN, Behlau M, Gama ACC, Teixeira LC. Atendimento em voz no Ambulatório de Fonoaudiologia do Hospital das Clínicas da Universidade Federal de Minas Gerais. Ciênc Saúde Coletiva. 2011;16(7):3119-29. http://dx.doi.org/10.1590/S1413-81232011000800012
21. Kent RD, Read C. The acoustic analysis of speech. San Diego: Singular; 1992.
22. Hirano M. Clinical examination of voice. New York: Springer; 1981.
23. Roman-Niehues G. Modificações vocais decorrentes da técnica fonoterapêutica de sons hiperagudos [dissertação]. Santa Maria: Universidade Federal de Santa Maria; 2008.
24. Silva RSA, Simões-Zenari M, Nemr NK. Impacto de treinamento auditivo na avaliação perceptivo-auditiva da voz realizada por estudantes de Fonoaudiologia. J Soc Bras Fonoaudiol. 2012;24(1):19-25. http://dx.doi.org/10.1590/S2179-64912012000100005
25. Camargo Z. Avaliação acústica e aerodinâmica da laringe. In: Campos CAH, Costa HOO, editores. Tratado de otorrinolaringologia. São Paulo: Roca; 2003. p. 814-23.
26. Lopes LW, Lima ILB, Almeida LNA, Cavalcante DP, Almeida AAF. Severity of voice disorders in children: correlations between perceptual and acoustic data. J Voice. 2012;26(6):819.e7-12. http://dx.doi.org/10.1016/j.jvoice.2012.05.008