Lehto L, Laaksonen L, Vilkman E, Alku P, Occupational voice complaints and objective acoustic measurements—do they correlate?, Logopedics Phoniatrics Vocology, 2006; 31 (4): 147-152.

http://www.informaworld.com/lpv

Logopedics Phoniatrics Vocology. 2006; 31: 147–152

Taylor & Francis
Taylor & Francis Group

ORIGINAL ARTICLE

Occupational voice complaints and objective acoustic measurements—do they correlate?

LAURA LEHTO[1,2], LAURA LAAKSONEN[3], ERKKI VILKMAN[2] & PAAVO ALKU[1]

[1]*Laboratory of Acoustics and Audio Signal Processing, Helsinki University of Technology, Finland,* [2]*Phoniatric Department, ENT Clinic, Helsinki University Central Hospital,* [3]*Nokia Research Center, Nokia Group, Finland*

Abstract
To enable the development of appropriate diagnostics and treatment for occupational voice disorders, this study addresses connections between subjective voice complaints and objective observations. The subjects of this study were 24 female customer advisors, who mainly use the telephone during their working hours. During one working day, at four different times, speech samples covering 20 minutes of telephone conversation by the customer service advisors (CSAs) were recorded. In addition, the CSAs filled in a questionnaire (visual analogue scale) concerning their voice problems. To represent the vocal symptoms three variables were used: vocal fatigue, hoarseness and a general sum-variable. A 5-minute sample was taken from recordings for further analyses. This included fundamental frequency, sound pressure level, alpha ratio (the ratio between the spectral energy below and above 1000 Hz) and number of vocal fold vibrations. In the objective acoustic measurements, it was found that fundamental frequency (F0) rose significantly during the working day. Also the self-reported voice symptoms increased significantly during the working day. However, correlations between vocal symptoms and acoustic measures were not found.

Key words: *Acoustic voice analysis, occupational voice, questionnaire study, voice symptoms*

Introduction

An occupational disease can be defined as a disease most likely to be caused by exposure at work. It is commonly known that occupational voice users suffer from voice symptoms to varying extents. The risk factors for voice professionals include background noise, poor room acoustics, long speaking distance, poor quality of air (dryness, dust), poor working posture and vocal loading *per se* by speaking or singing (1). People who use their voice professionally are at risk from occupational voice disorders. Voice disorders may involve changes in the larynx, which causes the laryngeal mechanism to fail to meet the functional voicing needs of the speaker.

Voice disorders often cause an audible deviation in voice quality (2), and they may affect both daily activities and social functioning (3). The inability to produce normal voice may be associated with stress, frustration, withdrawal and depression (4). The traditional voice evaluation procedures for quantifying the severity of voice disorders are structural, physiological, acoustic, and audio-perceptual analyses (3). It is also important to ask the subject to evaluate his/her voice symptoms, which can be interpreted as subjective evaluation of the voice problem.

Given the prevalence of self-reported subjective voice symptoms and the increasing possibility of using more advanced acoustic analyses, it is desirable to find connections between subjective voice complaints and objective observations to enable the development of appropriate diagnostics and treatment for occupational voice disorders. There are some previous studies within this field, but the results are not conclusive. In studies by Ma and Yiu (3) and Laukkanen et al. (5), the self-perceived voice problem did not correlate with the degree of voice quality impairment measured acoustically. However, the study by Rantala and Vilkman (6) showed a tendency toward a relationship between

Correspondence: Laura Lehto MA, Laboratory of Acoustics and Audio Signal Processing, Helsinki University of Technology, PO Box 3000, FIN-02015 TKK, Finland. Fax: +358 9 460 224. E-mail: laura.lehto@iki.fi

ISSN 1401-5439 print/ISSN 1651-2022 online © 2006 Taylor & Francis
DOI: 10.1080/14015430600654654

subjective voice complaints and objective acoustic measures of voice.

The present study is a part of a project which was launched on the basis of an initiative taken by the largest Finnish telecommunications operator, Sonera (currently known as TeliaSonera Finland Oyj). The motivation was that the sick-leave statistics of the company showed an over-representation of customer service advisors (CSA) and it was hoped that gathering information on the working conditions in a call-centre would help to shed light on the background of this problem. In addition, telephone marketers constitute an interesting subgroup of employees because their ability to work depends exclusively on their voice. Over the telephone, the speaker must rely merely on his/her voice, without getting support from body language or written communication.

The main aim in this study is to analyse whether any connections exist between subjective and objective measures of persons working on a vocally demanding task. The paper also describes briefly the self-perceived voice symptoms and the objective acoustic voice parameters during one working day.

Material and methods

Subjects of this study were 24 female customer advisors, who mainly use the telephone during their working hours. Their mean age was 28 years (range from 21 to 41 years) and their mean working experience was typically less than 1 year (mean 7 months, range from 1 month to 13 months) with the exception of one person who had a working experience of 10 years. Sixty-six percent of them were non-smokers. The length of the working day is 8 hours, including 30 minutes' lunch break and two 10-minute coffee breaks. Their employer estimates that a CSA works 5 hours per day exclusively in the speaking task. The subjects worked in an open-plan office, where individual working spaces are separated by movable partition walls. According to a work hygiene survey conducted by the Oulu Regional Institute of Occupational Health, the background noise level in the working space was 42 dB(A). The authorities of this local institute considered the background noise level to be low for open office work.

The subjects were asked about certain background factors that might have an effect on voice, e.g. hobbies including intense voice use, smoking, hearing loss, GERD (gastro-esophageal disease) and previous voice therapy. The subjects were also examined by a phoniatrician in the beginning of the study. This phoniatric examination included perceptual voice analysis and laryngeal examination with a mirror. Both the collection of the background factors and the phoniatric evaluation were performed in order to get a comprehensive view of the health status of the subjects. The effects of the background variables were not analysed, because our recent study on the same subjects showed that the background variables did not have a specific influence on subjective voice complaints ((7), pp.167–8). In the phoniatric examination, the subjects were normal except for some individuals with slight glottal oedema and irritation which correlated with smoking.

Data collection

The subjects completed a questionnaire about the state of their voices at four different times during the day: in the morning, before the lunch break, after the lunch break and at the end of the working day. The questionnaire consisted of 12 statements on vocal symptoms, as listed below.

1. My voice is overstrained
2. My voice is hoarse or husky
3. I have a feeling of a lump in my throat
4. I feel like I have a choker around my neck
5. I have a feeling of mucus in my throat and/or I need to clear my throat frequently
6. My throat is dry and/or itchy
7. My voice is weak/my voice doesn't resonate
8. My voice is tense or I feel I must make an effort when speaking
9. My voice is creaky
10. My voice often breaks when I speak
11. I feel short of breath/I need to gasp for air
12. My voice gets worse during the day

Statement no 12 was answered simply by 'yes' or 'no', while the other 11 questions were answered using the visual analogue scale (VAS) (e.g. (8)) with the range 'no symptoms like this' to 'a lot of symptoms like this'. The visual analogue scale is a commonly used instrument for assessing a subjective characteristic or attitude that is believed to be best represented somewhere on a continuum of values and is not amenable to direct measurement. From the subject's perspective this approach appears continuous—for example, self-experienced symptoms do not make discrete jumps, as a categorization into none, mild, moderate and severe would suggest (9). In this study, the line was 7.5 cm long. All the four times of the day were marked on the same VAS line each time the questionnaire was filled in.

To collect the acoustic material, telephone conversations by the CSAs were recorded four times during the working day. These four moments of recording were done at the same time as when completing the questionnaire of voice symptoms: in the morning, before the lunch break, after the lunch break and at the end of the working day. The recordings were made using a condenser microphone (AKG CK97–0 with AKG SE 300 B amplifier) and a DAT recorder (Sony TDC-D3) at the working place. The microphone was attached to the headset mouthpiece of the phone at approximately 3 cm from the mouth. A sinusoidal of 1 kHz at 82 dB SPL was recorded for calibration. The telephone conversation recordings were 20 minutes in duration. A 5-minute excerpt of each sample was analysed using a computer-based analysis program Puhetauko (10). The program classifies the excerpt into segments of voiced and unvoiced speech in a semiautomatic fashion. The following parameters were studied: fundamental frequency (F0), sound pressure level (SPL) and the ratio between the spectral energy below and above 1000 Hz (alpha ratio, AR) and the number of vocal fold vibrations (Index = F0 × phonation time).

Data analyses

On the basis of the literature on the hazards experienced by voice workers (e.g. (11–15)), we chose voice fatigue and hoarseness to represent vocal working ability (or its impairment). Also a general sum-variable was analysed. This sum-variable covers symptoms from number 1 to 11 by summing the VAS-scale estimates of each time of day.

A repeated measures analysis of variance (ANOVA) was used to analyse if there were any statistically significant changes in objective or subjective measures at different times of the day. This analysis was carried out using a repeated measures analysis of an SPSS statistical software package (Statistical Package for the Social Sciences, version 13.0 for Windows). Time of day with four instances was the within-subject variable for each subjective and objective measure, and the analysis also included Bonferroni *post hoc* test. For all objective measures, Mauchly's test showed that sphericity can be assumed (16). For the subjective data Mauchly's test showed that sphericity cannot be assumed and the significance level was therefore corrected using the Greenhouse-Geisser method.

Two analyses were conducted to study the correlations between changes in subjective and objective variables within time. Pearson's correlation was calculated for each objective-subjective-pair. Pearson's correlation reflects only linear relationships between two variables and it assumes that the variables are continuous and normally distributed. In addition, the variables should be independent of each other. A canonical correlation and Wilks's test of significance analysis were therefore performed to study the relation of two sets of variables: the objective and the subjective variables included in the study. Canonical correlation analysis is a multivariate technique to measure the many-to-many relationships between two data sets, and Wilks's lambda is commonly used to test the significance of canonical correlation.

Results

Objective acoustic parameters during working day

The results of the objective acoustic analyses are shown in Table I. The results of the ANOVA revealed that time of day did not have statistical significant effect on variables SPL, AR and Index. However, for F0 the *post hoc* test showed that the change between the 1st (the beginning of the day) and the 4th (end of the day) time of the day was significant ($p = 0.019$). These results are presented in Table II.

Subjective symptoms during working day

The subjective symptoms experienced during the working day are presented at Table III. Time of the day showed a very large effect on all three subjective measures (Table IV). The detailed results from the Bonferroni *post hoc* test are presented in Table V. For vocal fatigue, differences in each pair of times of the day are significant. The same is true for hoarseness, except between the beginning of the working day and

Table I. The mean, maximum and minimum values for the objective, acoustic measures. Acoustic measures are fundamental frequency (F0), sound pressure level (SPL), alpha ratio (AR; the ratio between energy below and above 1 kHz) and number of vocal fold vibrations (Index = F0 × phonation time). The times of the day are: 1 = at the beginning of the working day, 2 = before lunch, 3 = after lunch and 4 = at the end of the working day.

		Time of day			
Acoustic measure		1	2	3	4
F0 (Hz)	mean	185.7	186.0	186.6	189.3
	max	200.6	196.7	201.5	204.5
	min	174.8	165.6	166.6	179.0
SPL (dB)	mean	81.2	80.8	81.5	81.7
	max	91.8	88.0	87.9	90.8
	min	74.7	72.2	72.6	73.5
AR	mean	18.9	19.0	18.5	18.7
	max	23.5	24.2	22.9	24.1
	Min	16.8	15.57	15.1	14.8
Index	Mean	20084	21286	20297	21805
	Max	25985	30235	29722	32102
	Min	10461	12248	11097	11375

Table II. Results from the univariate tests of the repeated measures ANOVA (Sphericity Assumed) for objective acoustic parameters. The change between the 1st (the beginning of the day) and the 4th (end of the day) time of the day. Statistical parameters given are: degree of freedom (df), F value (F) and p-value (Sig.), where $p \leq 0.05$ indicates statistical significance, shown by an asterisk. Acoustic measures are fundamental frequency (F0), sound pressure level (SPL), alpha ratio (AR; the ratio between energy below and above 1 kHz) and number of vocal fold vibrations (Index = F0 × phonation time).

Acoustic measure	Df	F	Sig.
F0	3	3.531	0.019*
SPL	3	1.058	0.373
AR	3	1.887	0.140
Index	3	1.141	0.339

before lunch, and between the end of lunch break and the end of working day. Also the sum-variable changes significantly except between the end of lunch break and the end of working day.

Correlation between subjective voice complaints and objective acoustic voice measurements

Two analyses were conducted to study the correlations between the changes in subjective and objective variables within time. Pearson's correlation showed all the correlations to be insignificant. Also the canonical correlation analysis gave a level of 0.292, which is >0.05, and therefore according to this test there are no significant linear correlations between the subjective and objective data.

Table III. The mean, maximum and minimum values for voice symptoms 'My voice gets fatigued' and 'My voice gets hoarse'. The sum-variable covers symptoms from number 1 to 11 (see section data collection) by summing the visual analogue scale estimates of each time of day. The times of the day are: 1 = at the beginning of the working day, 2 = before lunch, 3 = after lunch and 4 = at the end of the working day. The maximum value for 'vocal fatigue' and 'hoarseness' is 7.5 and for 'sum-variable' 82.5.

		Time of day			
Symptom		1	2	3	4
Vocal fatigue	mean	1.0	1.9	2.3	3.0
	max	5.0	4.0	5.0	6.2
	min	0.2	0.5	0.3	0.3
Hoarseness	mean	1.6	1.9	2.6	3.2
	max	5.0	4.0	4.8	5.9
	min	0.3	0.6	0.3	0.3
Sum-variable	mean	11.6	17.2	22.9	27.0
	max	48.3	39.9	43.4	63.5
	min	3.6	5.9	3.5	3.6

Table IV. Results from the univariate tests of the repeated measures ANOVA (Greenhouse-Geisser) for subjective parameters. Statistical parameters given are: degree of freedom (df), F value (F) and p-value (Sig.), where $p \leq 0.05$ indicates statistical significance, shown by an asterisk. The sum-variable covers symptoms from number 1 to 11 (see section Data collection) by summing the visual analogue scale estimates of each four times of the working day.

Symptom	df	F	Sig.
Vocal fatigue	1.805	27.836	0.000*
Hoarseness	1.842	15.700	0.000*
Sum-variable	1.677	33.518	0.000*

Discussion

In many previous studies, a F0 rise during vocal loading has been considered a physiologically based normal phenomenon. This has been observed in both laboratory (17–20) and field conditions (21,22). In the present study, the F0 rise was systematic but so small that it can be assumed that the F0 rise alone does not increase the risk of an occupational voice disorder. F0 and SPL levels of the CSAs were much lower than those of teachers (cf. (22)). The main reason for this appears to be that the background noise level was low despite the working space being an open-plan office. The SPL level of speech corresponds approximately to 55 dB at 1 m, i.e. to normal or even soft speaking voice. Also the findings of the phoniatric examination support that the vocal loading on the subjects does not seem to be heavy enough to cause organic changes, at least during the relatively short time they had spent in their current occupation. For example, there were no instances of diagnosed laryngitis, which is considered the most common organic finding associated with vocal loading (e.g. (15)).

However, the self-perceived voice symptoms turned out to change significantly during the working day. In particular, the measurement of vocal fatigue seems to be a subjective measurement relating to extensive voice use. In addition, hoarseness and the sum-variable indicated that there is an increase in the self-perceived symptoms of CSAs during working day.

A correlation between subjective and objective measures would give important information of voice symptoms, occupational voice disorders, and the effect of voice therapy and training. So far, numerous studies have looked for correlations between perceived voice quality and objective measures (23–29). In contrast to this, studies of self-perceived subjective and objective measurements on voice are sparse (3,5,6). In addition, these studies have not yet reached unanimous conclusions.

Table V. Results from the Bonferroni *post hoc* test for subjective parameters. Time of day is the within-subject variable: 1 = at the beginning of the working day, 2 = before lunch, 3 = after lunch and 4 = at the end of the working day. Column Sig. represents p-values, where $p \leq 0.05$ indicates statistical significance, shown by an asterisk. The sum-variable covers symptoms from number 1 to 11 (see section data collection) by summing the visual analogue scale estimates of each four times of day.

						95% Confidence intervals	
Symptom	Time of day (I)	Time of day (J)	Mean Difference (I-J)	Standard error	Sig.	Lower bound	Upper bound
Vocal fatigue	1	2	−0.833	0.226	0.007*	−1.485	−0.181
		3	−1.271	0.203	0.000*	−1.856	−0.685
		4	−1.954	0.320	0.000*	−2.879	−1.030
	2	3	−0.438	0.130	0.016*	−0.812	−0.063
		4	−1.121	0.197	0.000*	−1.690	−0.551
	3	4	−0.683	0.196	0.012*	−1.248	−0.118
Hoarseness	1	2	−0.308	0.245	1.000	−1.017	0.400
		3	−1.004	0.247	0.003*	−1.717	−0.292
	2	3	−0.696	0.153	0.001*	−1.138	−0.254
		4	−1.238	0.230	0.000*	−1.900	−0.575
	3	4	−0.542	0.207	0.093	−1.139	0.056
Sum-variable	1	2	−5.579	1.341	0.002*	−9.449	−1.709
		3	−11.208	1.444	0.000*	−15.377	−7.039
		4	−15.400	2.442	0.000*	−22.449	−8.351
	2	3	−5.629	0.913	0.000*	−8.265	−2.993
		4	−9.821	1.557	0.000*	−14.315	−5.327
	3	4	−4.192	1.730	0.142	−9.184	0.801

An example of new research where self-perceived symptoms and objective acoustic measurements have been linked together is the recent study by Jonsdottir et al. (21). They studied female teachers' voices during a working day with and without electronic sound amplification. Although F0 is claimed to rise as a consequence of extensive voice use (17–20,22), Jonsdottir et al. (21) found that F0 and SPL increased more when amplification was used. This was despite the fact that with a sound amplifier the teacher is able to use natural fundamental frequencies and intensities. Additionally, the subjects' self-reported voice complaints suggested less vocal fatigue when amplification was used. This supports the argument that a vocal loading-related increase in F0 and SPL as such is not always a sign of vocal fatigue.

The definition of a voice problem is not at all straightforward. It can be seen as a complex of self-reported symptoms and clinically observed signs (30). This definition is in line with ICIDH-2, the new version of the International Classification of Impairments, Disabilities and Handicaps, proposed by the World Health Organisation (31). Therefore, if a person reports sufficient concerns and functional disruption in voice, his/her opinion should not be ignored. However, it is important to continue the search for the connection between voice complaints and the objective measurements. In the future, a large variety of acoustic parameters should be used in studying occupational voice production by applying not only parameters that measure characteristics of the speech pressure signal but also measurements that quantify the source of the speech, the glottal flow.

Acknowledgements

The research was supported by Sonera Corporation, the Finnish Work Environmental Fund, the Academy of Finland (project number 201018), and the Finnish Cultural Foundation.

References

1. Vilkman E. Occupational risk factors and voice disorders. Logoped Phoniatr Vocol. 1996;21:137–41.
2. Coyle S, Weinrich B, Stemple J. Shifts in relative prevalence of laryngeal pathology in a treatment-seeking population. J Voice. 2001;15(3):424–40.
3. Ma EP-M, Yiu EM-L. Voice activity and participation profile: assessing the impact of voice disorders on daily activities. J Speech Lang Hear Res. 2001;44:511–24.
4. Smith E, Verdolini K, Gray S, Nichols S, Lemke J, Barkmeier J, et al. Effects of voice disorders on quality of life. J Med Speech Lang Path. 1996;4:223–44.
5. Laukkanen A-M, Järvinen K, Artkoski M, Waaramaa-Mäki-Kulmala T, Kankare E, Sippola S, et al. Changes in voice and subjective sensations during a 45-min vocal loading test in female subjects with vocal training. Folia Phoniatr Logop. 2004;56:335–46.
6. Rantala L, Vilkman E. Relationship between subjective voice complaints and acoustic parameters in female teachers' voices. J Voice. 1999;13:484–95.
7. Lehto L, Rantala L, Vilkman E, Alku P, Bäckström T. Experiences of a short vocal training course for call-centre customer service advisors. Folia Phoniatr Logop. 2003;55: 163–76.

8. Dejonckere P, Lebacq J. Acoustic, Perceptual, aerodynamic and anatomical correlations in voice pathology. ORL J Otorhinolaryngol Relat Spec. 1996;58:326–32.
9. Gould D, Kelly D, Goldstone L, Gammon J. Examining the validity of pressure ulcer risk assessment scales: developing and using illustrated patient simulations to collect the data. J Clin Nurs. 2001;10:697–706.
10. Bäckström T. Development of an analysis environment for clinical analysis of continuous speech. Master Thesis, Helsinki University of Technology, Department of engineering Physics and Matematics, 2001. Available from: http://www.-acoustics.hut.fi/publications/files/theses/backstrom_mst.pdf
11. Sapir S, Atias J, Sharhar A. Symptoms of vocal attrition in women army instructors and recruits: results from a survey. Laryngoscope. 1990;100:991–4.
12. Sapir S, Keidar A, Mathers-Schmidt B. Vocal attrition in teachers: survey findings. Eur J Disord Commun. 1993;28: 177–85.
13. Scott S, Robinson K, Wilson JA, Mackenzie K. Patient-reported problems associated with dysphonia. Clin Otolaryngol. 1997;22:37–40.
14. Koufman J, Blalock P. Vocal fatigue and dysphonia in the professional voice users: Bogart-Bacall-syndrome. Laryngoscope. 1998;93(suppl 5):493–8.
15. Sala E, Laine A, Simberg S, Pentti J, Suonpää J. The prevalence of voice disorders among day care center teachers compared with nurses: A questionnaire and clinical study. J Voice. 2001;15(3):413–23.
16. Mauchly J. Test for sphericity of a normal n-variate distribution. Ann Math Stat. 1940;11:204–9.
17. Gelfer M, Andrews M, Schmidt C. Effects of prolonged loud reading on selected measures of vocal function in trained and untrained singers. J Voice. 1991;5(2):158–67.
18. Stemple J, Stanley J, Lee L. Objective measures of voice production in normal subjects following prolonged voice use. J Voice. 1995;9(2):127–33.
19. Lauri E-R, Alku P, Vilkman E, Sala E, Sihvo M. Effects of prolonged oral reading on time-based glottal flow waveform parameters with special reference to gender differences. Folia Phoniatr Logop. 1997;49:234–46.
20. Vilkman E, Lauri E-R, Alku P, Sala E, Sihvo M. Effects of prolonged oral reading on F0, SPL, subglottal pressure and amplitude characteristics of glottal flow waveforms. J Voice. 1999;13(2):303–15.
21. Jonsdottir V, Laukkanen A-M, Vilkman E. Changes in teachers' speech during a working day with and without electric sound amplification. Folia Phoniatr Logop. 2002;54: 282–7.
22. Rantala L, Vilkman E, Bloigu R. Voice changes during work: Subjective complaints and objective measurements for female primary and secondary school teachers. J Voice. 2002;16: 344–55.
23. Askenfelt A, Hammarberg B. Speech waveform perturbation analysis: A perceptual-acoustical comparison of seven measures. J Speech Hear Res. 1986;29:50–64.
24. Hammarberg B, Fritzell B, Gauffin J, Sundberg J. Acoustic and perceptual analysis of vocal dysfunction. J Phon. 1986;14: 533–47.
25. Södersten M, Hammarberg B. Effects of voice training in normal-speaking women: Videostroboscopic, perceptual, and acoustic characteristics. Scand J Log Phon. 1993;18:33–42.
26. Schmidt C, Andrews M, McCutcheon J. An acoustical and perceptual analysis of the vocal behavior of classroom teachers. J Voice. 1998;12(4):434–43.
27. Munos J, Mendoza E, Fresneda M, Carballo G, Lopez P. Acoustic and perceptual indicators of normal and pathological voice. Folia Phoniatr Logop. 2003;55:102–14.
28. Bhuta T, Patrik L, Garnett J. Perceptual evaluation of voice quality and its correlation with acoustic measurements. J Voice. 2004;18(3):299–304.
29. Speyer R, Wieneke G, Dejonckere P. Documentation of progress in voice therapy: perceptual, acoustic and laryngostroboscopic findings pretherapy and posttherapy. J Voice. 2004;18(3):325–40.
30. Verdolini K, Ramig L. Review: Occupational risks for voice problems. Logoped Phoniatr Vocol. 2001;26:37–46.
31. International Classification of Impairment, Disability and Handicap. Geneva, Switzerland: World Health Organization; 2001.