Coll. Antropol. **24** (2000) 2: 509–519
UDC 572.2612.78
Original scientific paper

Interpopulation Differences in Acoustic Characteristics of Phonation

G. Kovačić[1] and M. Heđever[2]

[1] The Artists Medical Center, University Hospital Dubrava, Zagreb, Croatia
[2] Department of Speech and Language Pathology, Faculty of Special Education and Rehabilitation, University of Zagreb, Zagreb, Croatia

ABSTRACT

The purpose of this study was to investigate possible differences in acoustic characteristics of phonation between populations of European and African origin. The subjects were 33 adult males divided in two groups. Group One consisted of 17 men of African origin, and Group Two included 16 men of European origin. All subjects were without vocal pathology at the time of the investigation, smokers and non-smokers. Sustained phonation of the vowel /a/ was acoustically analyzed by the Real-time Frequency Analyzer (Bruel and Kjær, type 2123). Variables included f_0, intensity of f_0, intensity of harmonics 1–7, jitter and noise level intensity. One-way variance analysis showed statistically significant difference between the two groups in intensity of the second harmonic only. The same analysis has been repeated with non-smokers and showed statistically significant differences in intensities of the second and the third harmonic leading to assumption that there may be fine differences in vocal fold vibration between Group One and Group Two. Factor congruence analysis showed differences between samples in factor structures. It could be possible that these differences reflect psychoacoustic level.

Introduction

Human species show the greatest phenotype variability among all the living species on our planet. Biological variations among humans are the result of the dynamic process of evolution as well as interaction of genotype and enviroment[1]. Skin color is the oldest criteria in human population differentiation, but there are other visible characteristics concerning body morphology and physiology such as height, body constitution, head index, facial shape, nasal index, eye shape and color, lip shape, hair texture and color, etc.[2,3,4,5]. Over the past few decades there has been an explosion in number of techniques developed to examine biological

Received for publication February 02, 1999.

variations among human populations (serological examinations, etc.)[6,7].

Aim of the present study was to investigate interpopulation distance in acoustic characteristics of phonation between men of African origin, and men of European origin. It is known that there are phenotype variations in nasal and oral cavity which both are important in finalizing the quality of the voice by the acoustical effect of resonance. Nasal index is one of the characteristics of human populations and is defined as a relationship between width and length of nose expressed in percentages. Anthropological researches have shown close relationship between climatic conditions (temperature, humidity, etc.) and nasal index[1,2]. The shape of the oral cavity is defined by jaw, which is also one of the physical characteristics of human populations[4]. However, less is known about interpopulation differences in laryngeal structure and its' biomechanics that might account for possible interpopulation differences in the quality of the glottal source spectrum. The only investigation that has addressed possible differences in laryngeal anatomy is that of Boshoff (according to Walton and Orlikoff[8]) published in 1945. The author found African larynx to be broader and stronger in comparison with Caucasian larynx, and concluded that this might cause differences in vocal characteristics as well. That was the most important motive in this research. Are there any significant differences in the harmonic content and spectral shape between voice samples of men of African and men of European origin, as a result of some fine differences in details of laryngeal apparatus? – that was the question the present study tried to answer.

There are very few researches concerning this subject. Hollien and Malcik[9] reported possible interpopulation difference in speaking fundamental frequency (f_0), which they found to be lower in black speakers compared to white. The investigations of Hudson and Holbrook[10,11] have also shown that the average speaking and reading f_0 in the population of black females and males was slightly lower than in the population of white females and males. At the same time, f_0 range was wider in the population of black females and males. One of the recent researches of Awan and Mueller[12] showed the differences in speaking f_0 among African American, Caucasian and Hispanic kindergarten children; African American children had lower speaking f_0 than Caucasian children whose speaking f_0 was lower compared to Hispanic children. Wheat and Hudson[13] reported speaking f_0 to be lower in 6-year-old black boys and girls compared to white children of the same age. At the beginning of the 70s, Krogman (according to Awan and Mueller[12]) suggested that possible differences in speaking f_0 could be the result of the anatomical differences between these populations.

However, there are some recent data that found no interpopulation differences in speaking f_0. A study of Morris[14] indicated that no significant differences were found in speaking f_0 among the African American boys in comparison to the white American boys at the age of 8–10.

Researches that have focused on interpopulation differences in the mean f_0 of sustained phonation are even fewer. The data of Mayo, and Steinsapir et al., both according to Walton and Orlikoff[8], did not show any significant differences between black and white subjects. Sapienza[15] had also examined acoustic characteristics of voice production based on vowel samples in black and white adult speakers of both sexes and found no significant differences between two samples of subjects in f_0.

Subjects and methods

The subjects were adult males, volunteers. In respect with the aim of this study, two groups of subjects were formed-Group One and Group Two. Group One included 17 subjects, Africans and African Americans, with an average age of 36. Group Two consisted of 16 subjects, Europeans and Americans of European origine. Their mean age was 31.5. The details on subjects are shown in Table 1.

TABLE 1
DETAILS ON SUBJECTS OBTAINED FROM THE QUESTIONNAIRE

Sub. No.	Age /year/	Counry of Birth	Mother Lanuage	Smo-king	Information on Mother		Information on Father	
					Counry of Origin	Ethnic Group	Counry of Origin	Ethnic Group
1.	50	USA	English	No	USA	Afr. American	USA	Afr. American
2.	31	USA	English	No	USA	Afr. American	USA	Afr. American
3.	41	USA	English	No	USA	Black	Cuba	Black
4.	41	USA	English	Yes	USA	Afr. American	USA	Afr. American
5.	41	USA	English	No	USA	Negro	USA	Negro
6.	49	USA	English	No	USA	Black	USA	Black
7.	29	Gabon	French	No	Gabon	(no answer)	Cameroon	(no answer)
8.	39	USA	English	No	Jamaica	Black	USA	Black
9.	33	Zimbabwe	Shona	No	Zimbabwe	African	Zimbabwe	African
10.	33	Zimbabwe	Shona	No	Zimbabwe	Black African	Zimbabwe	Black African
11.	31	USA	English	No	USA	Black	USA	Black
12.	26	Nigeria	English	No	Nigeria	Efik	Nigeria	Izon
13.	35	Uganda	Luo	No	Uganda	Luo	Uganda	Luo
14.	24	USA	English	No	USA	Afr. American	USA	Afr. American
15.	28	USA	English	Yes	USA	Negro	USA	Negro
16.	41	Kenya	Kikuyu	No	Kenya	Kikuyu	Kenya	Kikuyu
17.	46	Kenya	Luhya	No	Kenya	Luhya	Kenya	Luhya
18.	30	USA	English	No	USA	White	USA	White
19.	25	Germany	German	Yes	Germany	European	Germany	European
20.	26	USA	English	No	USA	White	USA	White
21.	37	USA	English	No	USA	Caucasian	USA	Caucasian
22.	40	Croatia	Croatian	No	Croatia	Croatian	Croatia	Croatian
23.	30	USA	English	No	Germany	Caucasian	USA	Caucasian
24.	27	USA	English	No	USA	Caucasian	USA	Caucasian
25.	35	Croatia	Croatian	Yes	Croatia	Croatian	Croatia	Croatian
26.	24	Croatia	Croatian	Yes	Croatia	Croatian	Croatia	Croatian
27.	53	Croatia	Croatian	Yes	Croatia	Croatian	Croatia	Croatian
28.	31	Belarus	Belarus	No	Belarus	Belarus	Belarus	Belarus
29.	29	Finland	Croatian	Yes	Croatia	Croatian	Croatia	Croatian
30.	34	Croatia	Croatian	Yes	Croatia	Croatian	Croatia	Serbian
31.	23	Croatia	Croatian	Yes	Croatia	Croatian	Croatia	Croatian
32.	27	Croatia	Croatian	Yes	Croatia	Croatian	Croatia	Croatian
33.	33	Croatia	Croatian	No	Croatia	Croatian	Serbia	Croatian

Important note: The details in the table are based on a questionnaire. The variety of the data on an item *ethnic group* is with respect to each subject's report. Abreviation *Afr.* stands for African.

Each of the 33 subjects were healthy and free from any ear-nose-throat problem at the time of participation. There were no vocal professionals. The only criteria that differentiated two groups was smoking. In the Group One there were two smokers, and in the Group Two eight. Following the effect of smoking on voice production, smokers were taken out and the analysis of variance was repeated with non-smokers. In order to view the harmonic content, set of twelve variables related to sustained phonation of the vowel /a/ was defined. This task was designed to remove as many linguistic information as possible.

Variables:

f_0-Hz = fundamental frequency (f_0) in Hz
f_0-dB = f_0 intensity
jitter = approximate measure of jitter expressed in bandwidths of 1/24th octave concentrated within the top of 10 dB of the fundamental frequency (f_0)
numb-harm = the number of harmonics clearly seen in one sequence along spectrum where the elevated spectral noise does not interfere with the intensity of harmonics
noise-coef = noise coefficient expressed as a ratio between the noise intensity level at 1000 Hz and f_0 intensity
delta(f_0-f_1) = intensity difference between f_0 and f_1
delta(f_0-f_2) = intensity difference between f_0 and f_2
delta(f_0-f_3) = intensity difference between f_0 and f_3
delta(f_0-f_4) = intensity difference between f_0 and f_4
delta(f_0-f_5) = intensity difference between f_0 and f_5
delta(f_0-f_6) = intensity difference between f_0 and f_6
delta(f_0-f_7) = intensity difference between f_0 and f_7*

Subjects were given a questionnaire that provided information on age, motherland, first language, other languages, vocal and general health status, profession, smoking status, voice-related activities, such as singing, acting, etc. Sustained phonation samples were recorded in a quiet room. Each subject was instructed to produce sustained phonation of the vowel /a/ twice, in a comfortable manner for at least 4 seconds. The free field measurement microphone (*Bruel & Kjær*, *type 4133*) was placed 8 cm from subjects mouth and was connected to the *Real-time Frequency Analyzer* (*Bruel & Kjær, type 2123*) through preamplifier (*Bruel & Kjær, type 2639)*. All recordings were made onto diskettes.

Statistical analyses were based on values of the acoustic parameters that were defined as variables. As two recording samples (two source spectrums) were made, the mean value for each variable was calculated. The differences between two groups of subjects were tested by a variance analysis set in a program SPSS-WIN. Factor structures of variables were derived by the method of principal-axis factor analysis (PCOMPA_N program), with the PB extraction criteria using orthoblique rotation. This program conducts the normalization of variables, thus minimizing the negative influence of asym-

* **Note:** Intensity levels (SPL) were expressed in dB.
The first harmonic next to the fundamental (f_0) was considered as the first harmonic (f_1), the next as the second harmonic (f_2), etc.
Variables **delta(f_0-f_n)** showed the intensity difference between n^{th} harmonic and f_0 calculated by formula: delta(f_0-f_n) = I f_0-I f_n, where I f_0 = f_0 intensity, I f_n = n^{th} harmonic intensity. It is important to stress that higher mean value of delta(f_0-f_n)-variables means lower intensity level of f_n which has to be considered in interpretation of the results.

metric distributions on results of factor analysis.

Results and discussion

The variance analysis of variables of the acoustic characteristics of phonation

As seen in Table 2, the only statistically significant difference (p=0,05) has been found on a variable **delta(f_0-f_2)** showing that the intensity of the second harmonic (f_2) was significantly lower in the Group One. Graph 1 shows an average harmonic spectrums, that is the intensity levels of harmonics 1–7 for both groups. Gradual intensity decline up to the frequency range of 400–500 Hz is clearly seen for Group One. In the light of the source-filter theory, the energy distribution of harmonics along spectrum depends on glottis as the source of the signal[16], and that leads to assumption that glottal source characteristics may be different in samples of this investigation. As an addition, it can be seen that jitter values are also different although not significantly. The mean $\mathbf{f_0}$ value was 107 Hz in Group One, and 105 Hz in Group Two, which is very similar to the values for these two populations reported by Walton and Orlikoff[8].

Smoking was the only criteria that differentiated two groups of subjects. It is known that there are interpopulation differences in tobacco-related diseases. Some recent researches showed that blood serum cotinine levels were higher among smokers of African origin and that nicotine intake per cigarette was 30% greater in these subjects compared to male smokers of European origin[17,18,19]. Knight et al.[20] found urinary and hair cotinine concentration to be higher in young second-hand smokers of African origin compared to young second-hand smokers of European origin, although the subjects of African origin were exposed to less cigarettes than second-hand smokers of European origin. These findings may serve as a marker of higher smoking-related disease risk in smokers of African origin. Knowing the effect of smoking on voice production, smokers were taken out from each

TABLE 2.
VARIANCE ANALYSIS OF THE ACOUSTIC CHARACTERISTICS OF PHONATION FOR THE GROUP ONE (1) AND GROUP TWO (2)*

Variable	M1	M2	SD1	SD2	F-ratio	Prob.
f_0-Hz	107.28	104.93	12.221	14.098	.26	.61
f_0-dB	84.38	85.01	5.188	5.634	.11	.73
jitter	.97	.78	.449	.576	1.11	.29
numb-harm	12.35	11.43	1.998	1.209	2.49	.12
noise-coef	.70	.69	.056	.060	.14	.70
delta(f_0-f_1)	3.31	4.11	2.174	3.278	.68	.41
delta(f_0-f_2)	**8.05**	**5.78**	**3.856**	**2.620**	**3.86**	**.05**
delta(f_0-f_3)	8.64	5.65	5.357	6.008	2.28	.14
delta(f_0-f_4)	5.87	5.16	5.945	6.295	.11	.74
delta(f_0-f_5)	3.30	3.35	8.015	6.723	.00	.98
delta(f_0-f_6)	5.11	4.00	6.922	5.380	.26	.61
delta(f_0-f_7)	7.44	7.38	5.589	7.178	.00	.97

N=33, N_1=17, N_2=16

* Statistically significant differences are bold and shaded.

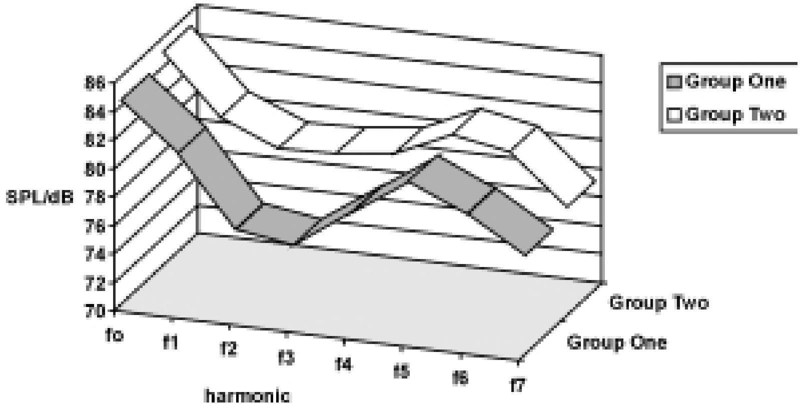

Fig. 1. Intensity levels of harmonics (f_0-f_7) in sustained phonation of the vowel /a/ – total sample

group and variance analysis has been repeated with non-smokers.

Statistically significant differences were found in two variables (Table 3); **the intensity of the second harmonic (f_2)**, which still was decreased in the harmonic spectrum of the Group One, **and the intensity of the third harmonic (f_3)**, which also became decreased. This significantly lower energy of harmonics mentioned above refers to frequency range between 300 and 450 Hz and is directly dependent upon glottal source characteristics. Together with the greater instability of the fundamental period (jitter) in the Group One, it might be supposed that spectral noise is greater along the same frequency range, all of which may represent psychoacoustical feature of the voice defined as roughness. Emanuel and Whitehead[21] found negative correlation between intensity levels of low-frequency

TABLE 3
VARIANCE ANALYSIS OF THE ACOUSTIC CHARACTERISTICS OF PHONATION FOR NON-SMOKERS OF THE GROUP ONE (1) AND GROUP TWO (2)*

Variable	M1	M2	SD1	SD2	F-ratio	Prob.
f_0-Hz	106.14	109.12	9.743	16.890	.29	.59
f_0-dB	85.72	85.80	2.919	2.068	.00	.94
jitter	.90	.75	.387	.801	.37	.54
numb-harm	12.73	11.37	1.791	1.505	3.32	.08
noise-coef	.69	.71	.043	.063	.49	.48
delta(f_0-f_1)	3.28	3.70	1.853	3.102	.16	.68
delta(f_0-f_2)	**8.23**	**5.02**	**3.999**	**2.402**	**4.26**	**.05**
delta(f_0-f_3)	**9.12**	**3.86**	**5.304**	**5.942**	**4.73**	**.04**
delta(f_0-f_4)	5.53	5.02	6.265	6.825	.03	.85
delta(f_0-f_5)	2.27	4.17	7.176	5.751	.41	.52
delta(f_0-f_6)	4.40	3.11	5.952	4.865	.27	.60
delta(f_0-f_7)	6.98	6.33	5.235	5.283	.07	.78

N=23, N_1=15, N_2=8

* Statistically significant differences are bold and shaded.

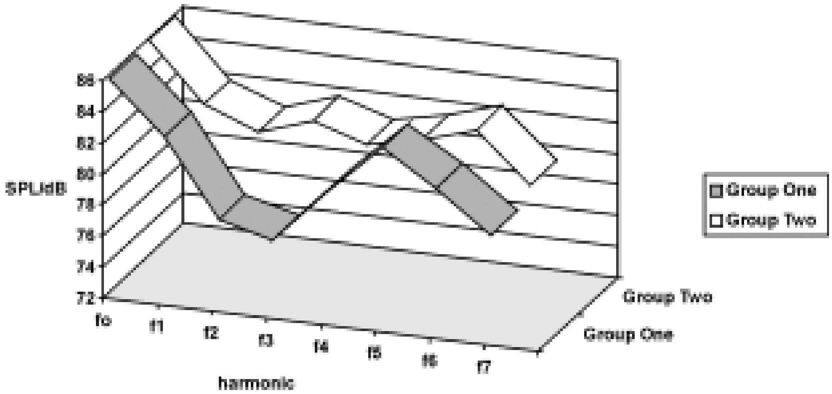

Fig. 2. Intensity levels of harmonics (f_0-f_7) in sustained phonation of the vowel /a/ – non-smokers

harmonics (f_1-f_5) and vowel roughness showing that vowel samples with lower energy of these harmonics (and particularly the second harmonic) refer to perception of increased roughness. However, as difference in **jitter** was not statistically significant in this study, and perceptual analysis was not conducted, it is only to suspect that roughness in vowel samples of the Group One is greater than in the Group Two.

Furthermore, $\mathbf{f_0}$ in non-smokers of the Group One was slightly lower and **the number of harmonics** tended toward significantly higher value in this sample of subjects.

Differences in harmonic energy distribution in spectrum between non-smokers of the Group One and Group Two are shown in **Fig. 2.**

Factor analysis and factor structure congruences of the acoustic characteristics of phonation

a) Group One

There were five significant factors explaining 88.8% of the variance (**Tables 4a** and **5**). However, in order to maintain

TABLE 4
NUMBER OF EXTRACTED FACTORS AND RELIABILITY

a) Group One

	Eigenvalue	Variance proport.	Cumm.	Reliability
Factor 1	3.863	0.322	0.322	0.717
Factor 2	3.124	0.260	0.582	0.624
Factor 3	1.937	0.161	0.744	0.482
Factor 4	1.012	0.085	0.829	0.668
Factor 5	0.709	0.059	0.888	0.449

b) Group Two

	Eigenvalue	Variance proport.	Cumm.	Reliability
Factor 1	4.423	0.369	0.369	0.727
Factor 2	2.634	0.212	0.589	0.692
Factor 3	1.705	0.142	0.731	0.686
Factor 4	1.143	0.095	0.826	0.441
Factor 5	0.636	0.053	0.879	0.319

TABLE 5
FACTOR STRUCTURES (S) OF THE ACOUSTIC CHARACTERISTICS OF PHONATION FOR THE GROUP ONE AND GROUP TWO*

	Group One					Group Two				
Variable	S_1	S_2	S_3	S_4	S_5	S_1	S_2	S_3	S_4	S_5
f_0-Hz	–0.306	0.493	0.076	–0.404	**–0.920**	**–0.740**	–0.333	–0.476	–0.032	–0.146
f_0-dB	–0.193	0.158	**0.749**	–0.629	0.182	0.521	–0.405	0.159	0.508	0.159
jitter	0.034	0.185	–0.260	**0.784**	0.061	0.057	0.274	**0.741**	0.364	–0.421
numb-harm	–0.032	–0.158	**0.931**	–0.183	0.016	0.048	0.204	–0.326	0.140	**0.976**
noise-coef	0.079	–0.522	–0.295	**0.847**	0.373	–0.094	0.569	–0.011	**0.895**	0.045
delta(f_0-f_1)	0.503	–0.353	–0.059	**0.749**	0.190	**0.836**	–0.105	0.255	0.127	0.278
delta(f_0-f_2)	**0.952**	–0.109	–0.048	0.280	0.171	**0.723**	–0.346	0.698	–0.421	–0.137
delta(f_0-f_3)	**0.896**	–0.005	0.109	0.317	0.171	**0.766**	–0.196	**0.893**	–0.158	0.013
delta(f_0-f_4)	**0.869**	0.206	–0.393	0.086	0.113	**0.858**	–0.384	0.527	–0.098	–0.073
delta(f_0-f_5)	**0.766**	0.441	–0.380	–0.106	–0.390	0.394	**–0.901**	0.211	–0.290	–0.211
delta(f_0-f_6)	0.288	**0.910**	–0.053	–0.410	–0.615	0.153	**–0.944**	0.221	–0.402	–0.095
delta(f_0-f_7)	–0.075	**0.928**	–0.146	–0.397	–0.389	0.323	–0.713	**–0.746**	–0.320	–0.367

better accuracy of the interpretation, only the factors with reliability above 0,60 will be reported.

The first and the most reliable factor was defined by **the intensities of the second (f_2), third (f_3), fourth (f_4) and fifth harmonic (f_5)**. In source spectrum of the Group One, the intensities of these harmonics varied together defining the frequency range between 200 and 650 Hz. This range was somewhat decreased compared to that of the Group Two (**Graph 1**). If emphasized, the part of this compact frequency range (200–400 Hz) produces nasality[22]. Therefore, it can be said that the first factor highlighted this particular quality of the voice of the Group One, but also the roughness, the quality of the voice characterized by the decreased harmonic-to-noise-ratio, and that is decreased intensity of the lower harmonics of the Group One of the present study.

The second factor was defined by **the intensities of the sixth (f_6)**, and **the seventh harmonic (f_7)** located in frequency range between 750 and 850 Hz.

Jitter, noise intensity level and **intensity of the first harmonic (f_1)** (all positively correlated) had the highest loadings on the fourth factor. The relationship between jitter and noise level intensity is understandable; if lower, jitter value indicates less irregularities in vocal fold vibration and implies less noise in source spectrum, and vice versa.

b) Group Two

Five significant factors were extracted explaining 87,9% of the variance (**Tables 4b** and **5**). **f_0**, and **intensities of the first (f_1), second (f_2), third (f_3)** and **fourth harmonic (f_4)** had high loadings on the first factor. They were positively correlated, defining the frequency range between 100 and 500 Hz. This frequency range builds up 50% of the total sound power produced by human voice mechanism and this factor had the greatest reliability in the Group Two.

The second factor was defined by **the intensities of the fifth (f_5)** and **the sixth harmonic (f_6)**. Both of their loadings were very high.

* The highest loadings are bold and shaded.

TABLE 6
FACTOR STRUCTURES CONGRUENCES FOR THE GROUP ONE (1) AND GROUP TWO (2)*

1 / 2	Factor 1	Factor 2	Factor 3	Factor 4	Factor 5
Factor 1	**0.829**	0.058	–0.057	0.253	0.342
Factor 2	–0.465	**–0.826**	0.108	0.494	0.626
Factor 3	0.707	0.312	–0.310	0.333	0.156
Factor 4	–0.353	–0.535	0.195	0.411	0.488
Factor 5	–0.102	–0.466	0.756	–0.065	0.292

The third factor was defined by **jitter,** and **intensities of the third (f_3)** and **the seventh harmonic (f_7).** Intensities of these two harmonics were in negative correlation with jitter.

As it can be seen, factor analysis extracted five factors for each sample of subjects. Two of them were somewhat similar-structures of the first factor of each sample (lower frequency range between 300 and 500 Hz) and structures of the second factor of each sample (higher frequency range between 600 and 800 Hz). Factor congruence coefficients between these factors were higher than 0.80 (**Table 6**). The other factor congruence coefficients were much lower. Therefore, there were much more differences than similarities in factor structures between the two groups of subjects.

In addition, it can be seen that in each group of subjects, there was one specific factor (the fifth factor in both groups) represented by only one variable. With very high loadings, these one-variable-factors (**f_0** in the Group One, and **the number of harmonics** in the Group Two) seemed to behave independently.

Conclusion

Vocal characteristics can be described in terms of acoustics and psychoacoustics. There are number of researches that had described human voice considering chronological age, gender, professional status, social background, vocal pathology, emotions, etc. However, there are very few researches that dealt with interpopulation variations in acoustic and psychoacoustic characteristics of the voice.

Gallois, Callan and Johnstone[23] examined the ability to perceive interpopulation differences in the voice. The results of their study showed that it was possible to identify the ethnicity of the speaker by listening to the voice. Coleman's data[24] suggested that correct population identification depended on the listener and his/her ethnical background. However, those and other results were based on speech-patterns which, even short-lasting, influence one's judgment and accuracy to identify the speaker's population background. Indeed, Mencel et al.[25] showed that utterance complexity and voicing may have an effect on correct population identification. They found that the listeners' accuracy to identify differences in voices between North American Indian children and non-Indian children was significantly higher for sentences versus vowels.

To investigate ability to perceive interpopulation differences based on the voice alone, content-free speech patterns should be analyzed and sustained phonation is one example of it. One of the very few researches that examined interpopulation differences in the mean f_0 of sustained phonation was that of Walton and Orli-

* The highest congruence coefficients are bold and shaded.

koff[8], which also showed that most of the listeners were successful in identification of the speaker's ethnical background based on listening to the isolated vowels.

The aim of the present study was to examine if there are any interpopulation differences in acoustic characteristics of phonation, as a result of possible differences in laryngeal apparatus[8]. A total sample consisted of 33 adult males, representing two populations. Group One consisted of 17 subjects of African origin, and Group Two consisted of 16 subjects of European origin. In order to remove as many linguistic information as possible, sustained phonation of the vowel /a/ was acoustically analyzed by a *Real-time Frequency Analyzer (Bruel & Kjær, type 2123).*

Complex data of the present study suggested that it is hard to judge on interpopulation distance based on acoustic characteristics of phonation between the two groups of subjects. The results of the variance analysis of the acoustic characteristics of voice of the two groups of subjects showed statistically significant differences in two variables only. These are the intensities of the second (f_2) and the third harmonic (f_3), both of which were lower in source spectrum of the Group One. Knowing that generation of these (low-frequency) harmonics is dependent on vocal fold characteristics[26], it is to conclude that there may be some fine differences in vocal fold vibration between population of African origin and population of European origin. Indeed, the instability of fundamental frequency (jitter) was greater in the Group One. That may contribute to lesser energy in low-frequency harmonics of the spectrum compared to the Group Two. It also may be suspected that voices of the Group One could be perceived as having greater roughness in comparison with the voices of the Group Two. Interestingly enough, in the study of Walton and Orlikoff[8], one of the characteristics given by listeners to the voices of the speakers of African origin was roughness.

The results of the factor analysis and congruence of the factor structures conducted on the same set of variables (f_0, intensity of harmonics 1–7, noise level, jitter) were very interesting, and showed that there were no similarities in acoustic characteristics of phonation between the two groups. It is probable that there were differences in latent generators that caused specific relationships among variables, resulting in qualitative differences of acoustic characteristics of phonation between groups. That might cause different perception of the voices of the groups representing different populations, and this subject enters the world of psychoacoustics. One must not forget that human ear is a very precise and sensitive analyzer.

The data presented here were also an attempt to begin to design investigations in which complex linguistic information should be avoided if interpopulation differences based on the voice alone are to be studied. Steady phonation appears to be the most proper voice sample to be used in comparative studies of interpopulation differences in acoustic characteristics of phonation. However, the results of the present study need to be taken with caution, and further investigations upon this sensitive subject are needed.

Acknowledgment

The part of this study was presented at the *24th Congress of the International Association of Logopedics and Phoniatrics* held in Amsterdam (Netherlands), August 23–27, 1998. The authors wish to thank to *Open Society Institute in Croatia* and *Croatian Musicians Society* for their financial support, which made the participation in the program of the *24th IALP Congress* possible.

R E F E R E N C E S

1. HIERNAUX, J.: Jednakost ili nejednakost rasa?. (Školska knjiga, Zagreb, 1975) — 2. HIRSCH, J.: Behavior-Genetic Analysis. (McGraw-Hill, Inc. 1967) — 3. ŠVOB, T.: Milenijski mitovi mržnje, Biološka kritika rasizma. (Durieux, Zagreb, 1995) — 4. TAED, D.: What Is Race?, Evidence From Scientists (UNESCO, Dep. of Mass Communication, Paris, 1952) — 5. OOMMEN, T. K., Int. Soc. Sci. J., 139 (1994) 83. — 6. COPRA, V. P., Homo, 43 (1992) 45. — 7. ALCIATI, G., E. LUCCHETTI, M. TOMMASEO, Homo, 43 (1992) 66. — 8. WALTON, J. H., R. F. ORLIKOFF, J Speech Hear Res, 37 (1994) 740. — 9. HOLLIEN, H., E. MALCIK, Speech Monographs, 29 (1962) 53. — 10. HUDSON, A. I., A. HOLBROOK, J Speech Hear Res, 24 (1981) 198. — 11. HUDSON, A. I., A. HOLBROOK, J Speech Hear Res, 25 (1982) 26. — 12. AWAN, S. N., P. B. MUELLER, J Speech Hear Res 39 (1996) 576. — 13. WHEAT, M. C., A. I. HUDSON, J Speech Hear Res 31 (1988) 724. — 14. MORRIS, R., J Commun Dis 30 (1997) 101–114. — 15. SAPIENZA, C. M., J Voice 11/4 (1997) 410–416. — 16. BAKEN, R. J.: Clinical Measurement of Speech and Voice (Singular Publishing Group, Inc. 1996) — 17. CARABALLO, R. S., G. A. GIOVINO, T. F. PECHACEK, P. D. MOWERY, P. A. RICHTER, W. J. STRAUSS, D. J. SHARP, M. P. ERIKSEN, J. L. PIRKLE, K. R. MAURER, JAMA 280 Jul (1998) 135–139. — 18. PEREZ-STABLE, E. J., B. HERRERA, P. JACOB III, N. L. BENOWITZ, JAMA 280 Jul (1998) 152–156. — 19. WAGENKNECHT, L. E., G. R. CUTTER, N. J. HALEY, S. SIDNEY, T. A. MANOLIO, G. H. HU, D. R. JACOBS, Am J Public Health 80 (1990) 1053–1056. — 20. KNIGHT, J. M., C. ELIOPOULOS, C. KLEIN, M. GREENWALD, G. KOREN, Chest 109 (1996) 446–450. — 21. EMANUEL, F. W, R. L. WHITEHEAD, J Speech Hear Res 22 (1979) 835. — 22. ŠKARIĆ, I.: Govorni dijelovi, III dio. In: Babić, S., D. Brozović, M. Moguš, S. Pavešić, I. Škarić (Ed.): Povijesni pregled, glasovi i oblici hrvatskog jezika (Globus, Zagreb 1991) — 23. GALLOIS, C., V. J. CALLAN, M. JOHNSTONE, J LANG Soc Psychol 3 (1984) 52. — 24. COLEMAN, L. M., J Black Psychol 3 (1976) 40. — 25. MENCEL, E., J. B. MOON, H. A. LEEPER, Folia Phoniatr 40 (1988) 175–182. — 26. SHOJI, K., E. REGENBOGEN, J. D. YU, S. M. BLAUGRUND, J Voice 5/1 (1991) 34.

G. Kovačić

Zdravstveni centar za umjetnike, Klinička bolnica Dubrava, Aleja G. Šuška 6, 10000 Zagreb, Croatia

INTERPOPULACIJSKE RAZLIKE U AKUSTIČKIM KARAKTERISTIKAMA FONACIJE

S A Ž E T A K

Cilj ovog istraživanja bio je ispitati moguće razlike u akustičkim karakteristikama fonacije između populacija Europskog i Afričkog porijekla. Ispitanici su bili odrasli muškarci, njih tridesetitroje, podijeljeni u dvije grupe. Grupa Jedan sastojala se od 17 muškaraca Afričkog porijekla, a Grupa Dva od 16 muškaraca Europskog porijekla. Niti jedan ispitanik, pušač i nepušač, nije imao poremećaj glasa u trenutku ispitivanja. Akustički je analizirana produžena fonacija vokala /a/ analizatorom frekvencija u realnom vremenu *(Bruel and Kjær, type 2123)*. Mjerene varijable bile su f_0, *intenzitet* f_0, *intenzitet harmonika 1–7, jitter* i *intenzitet šuma*. Analizom varijance pronađena je statistički značajna razlika između dviju grupa samo u intenzitetu drugog harmonika. Ista analiza bila je ponovljena na nepušačima. Značajne razlike pronađene su u intenzitetima drugog i trećeg harmonika što ukazuje na suptilne razlike u titranju glasiljki između Grupe Jedan i Grupe Dva. Analiza faktorskih kongruencija pokazala je da postoje razlike između ispitivanih grupa u faktorskim strukturama. Moguće je da se ove razlike odražavaju na psihoakustičkoj razini.