Acoustic analysis of Hungarian vowels

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II. SPEECH ANALYSIS

A. ACOUSTIC ANALYSIS OF HUNGARIAN VOWELS

T. Tarnóczy

1. Introduction

Several years ago (1939-42) the author determined the resonance data of the vowel forming cavities applied to Hungarian vowels (4)(5)(6). Those investigations were carried out in part by means of Fourier analysis of oscillograms and in part by exciting the cavities from the outer or the inner side. The experimental technique of that time did not allow the exact determination of formant structure. Therefore, it seemed to be necessary to control and complete the former results.

In the autumn of 1964 at the Speech Transmission Laboratory the author had the opportunity of undertaking new studies of the formant structure of Hungarian vowels. The experiments were carried out with four male and four female subjects, all native Hungarians. Thirty-two two-syllable Hungarian words acted as a test-text. This text contained all Hungarian vowels both in stressed and unstressed position more than once, and also in connection with various consonants. Spectrum analysis was made principally by the Ray Electric Sona-Graph, with some modifications recommended and developed by the Speech Transmission Laboratory (2)(3).

2. The vowel-system

According to the general pronunciation, the Hungarian vowel-system contains 14 phonemes. To this number can also be added further 3 dialectal variants, differing from the normal ones in duration only. The 14 phonemes are introduced in the following vowel diagram:

\[
\begin{align*}
\text{i:} & : \text{i} \\
\text{e:} & \\
\text{y:} & : \text{y} \\
\text{e} & : \text{e} \\
\text{a} & : \\
\text{o:} & : \text{o} \\
\text{u:} & : \text{u}
\end{align*}
\]

* see p. v
Two of the vowels [a] and [ɛ], which represent the largest relative occurrence in Hungarian (together more than 20% of all sounds) are only short, two others [a] and [ɛ] are only long in common pronunciation. Three vowels [u]; [y], and [i] occur in both forms: short and long, but with the same quality. The last two [ɔ] and [ø] have according to the phoneticians two forms: the long phonemes [ɔ:] and [ø:] and the short ones [ɔ] and [ø].

3. Results

Fig. II-A-1 shows the spread of the formant data of four male persons. The frequency of the second formant (logarithmic scale) vs first formant frequency (linear scale) pattern contains 254 evaluated data. The phoneme areas indicated cover 98% of the field of spread. Fig. II-A-2 pertains to the same presentation of data for female persons. (256 data). No differentiation has been made between short-long pairs. The mean values of the formant area are to be seen in Table II-A-1.

<table>
<thead>
<tr>
<th></th>
<th>F1</th>
<th>F2</th>
</tr>
</thead>
<tbody>
<tr>
<td>u</td>
<td>290</td>
<td>830</td>
</tr>
<tr>
<td>o</td>
<td>430</td>
<td>920</td>
</tr>
<tr>
<td>a</td>
<td>580</td>
<td>1000</td>
</tr>
<tr>
<td>e</td>
<td>630</td>
<td>1480</td>
</tr>
<tr>
<td>ɛ</td>
<td>400</td>
<td>1530</td>
</tr>
<tr>
<td>ɔ</td>
<td>280</td>
<td>1800</td>
</tr>
<tr>
<td>y</td>
<td>350</td>
<td>2150</td>
</tr>
<tr>
<td>i</td>
<td>270</td>
<td>2500</td>
</tr>
</tbody>
</table>

As can be seen in Table II-A-1 and also in Fig. II-A-3, there is a substantial shifting of the first female formant compared with males in [a] and [ɛ] only, while the shift in the second formant is apparent for all other vowels except [u], [ɔ], and [a]. These male-female differences are similar to those reported by Fant for Swedish (1).

3.1 First-second formant frequency patterns of choruses

If many people speak the same text at the same time, then we have a speech chorus. It is a plausible assumption that hereby the common properties of a certain speech sound are emphasized while the
Fig. II-A-1. F1-F2 formant patterns of Hungarian vowels. Four male voices. 254 data.
FIRST FORMANT FREQUENCY

SECOND FORMANT FREQUENCY
Fig. II-A-3. F1-F2 formant patterns from the chorus method (closed signs for males, open signs for females) compared with the formant data of Fig. II-A-1 and Fig. II-A-2 (solid contours for males and broken line contours for females).
individual features are averaged out. This method has earlier been used by the author to determine the spectra of fricative sounds. The present study, on the other hand, is the first successful application of the chorus method to determine also the formant locations of vowel sounds. The two choruses consisted of three males and three females, selected from the group of subjects. The text was the same as above.

The results did not always fully come up to our expectations, e.g., several times the formant places were too wide. In Fig. II-A-3 you can see the results for men (closed signs) and for women (open signs), drawn into the formant areas of Figs. II-A-1 and II-A-2. It is interesting that the spreads of the chorus data from repeated phonations are not essentially less than the spread among individuals. This indicates that the first and second formant frequencies of a vowel are more sensitive to the stress, speech melody, and other utterance peculiarities than to individual features.

3.2 The problem of [o] and [φ]

We have mentioned in point 2 that the shortening of Hungarian [o] and [φ] is supposed to be connected with quality modifications too. This statement, however, is founded upon linguistic and physiological criteria only. In order to study this problem, I separated all data of [o] and [φ] according to their stress and duration. In two-syllable Hungarian words the first vowel is always stressed, the second unstressed. So we had four combinations: stressed-long, stressed-short, unstressed-long, and unstressed-short. As may be seen in Fig. II-A-4, the unstressed-short combination shows a very different character from the other three. This is completely clear for [o] but also significant for [φ]. In the latter case we had less data, and the formant shifting of women also disturbed the phenomenon.

One can formulate the system as follows: the Hungarian short [o] and short [φ] tend to [ɔ] and [ɛ] respectively in unstressed positions only.

In order to further study this problem we have made and recorded various synthetic vowels sampled within the formant frequency data of Fig. II-A-4. The synthesis was made with the passive OVE, described elsewhere (1). The evaluation of these recordings will be made later on by Hungarian linguists.
Fig. II-A-4. The influence of stress and length on the quality of Hungarian vowels õ–ö and ø–ø. See text.
3.3 About the third and fourth formants

An exact determination of the frequencies of the third and fourth formants from the sonagrams is rather difficult. The spread is very large and frequently the data are not in conformity with one another. The figures show, however, some interesting tendencies. I do not find the data sufficient for statistics, and therefore the results are merely summarized in Table II-A-2. The tendencies found are the following: As the first formant frequency increases, the third formant frequency falls, and the converse relation holds.

<table>
<thead>
<tr>
<th></th>
<th>F₁</th>
<th>F₂</th>
<th>mean</th>
<th>F₄</th>
<th>mean</th>
</tr>
</thead>
<tbody>
<tr>
<td>u, y, i</td>
<td>200-350</td>
<td>2300-3000</td>
<td>2750</td>
<td>3200-3800</td>
<td>3500</td>
</tr>
<tr>
<td>c, ơ, e</td>
<td>300-500</td>
<td>2200-2900</td>
<td>2700</td>
<td>3250-3900</td>
<td>3600</td>
</tr>
<tr>
<td>e, ơ</td>
<td>450-650</td>
<td>2100-2700</td>
<td>3500</td>
<td>3400-4000</td>
<td>3700</td>
</tr>
<tr>
<td>a</td>
<td>750-900</td>
<td>2100-2500</td>
<td>3500</td>
<td>3600-4100</td>
<td>3900</td>
</tr>
<tr>
<td>u, y, i</td>
<td>200-350</td>
<td>2500-3200</td>
<td>3500</td>
<td>3200-4000</td>
<td>3600</td>
</tr>
<tr>
<td>c, ơ, e</td>
<td>300-500</td>
<td>2500-3000</td>
<td>3700</td>
<td>3300-4100</td>
<td>3700</td>
</tr>
<tr>
<td>e, ơ</td>
<td>450-750</td>
<td>2300-2800</td>
<td>3500</td>
<td>3500-4200</td>
<td>3850</td>
</tr>
<tr>
<td>a</td>
<td>700-1000</td>
<td>2300-2700</td>
<td>3600</td>
<td>3600-4200</td>
<td>4000</td>
</tr>
</tbody>
</table>

4. Acknowledgments

The author is indebted to Dr. Gunnar Pant for his kind permission to make some scientific research work at the Speech Transmission Laboratory. Further is to be acknowledged the valuable help of Mr. J. Mártony and Mr. K. Galyas in organizing and carrying out the experiments. I also owe thanks to Mr. A. de Serpa-Leitão for making the sonagrams and to Miss Eva Agelfors for the drafting.

References:


