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SOME EXPERIMENTS ON THE EFFECT OF VOWEL-CONSONANT TRANSITIONS UPON THE PERCEPTION OF PALATALIZATION IN ESTONIAN

1. **Introduction.** Palatalization in Estonian has been a controversial subject for about three centuries.¹ The phenomenon has been regarded, on the one hand, as essentially a phenomenon associated with the consonant system (this is also the view of recent investigators, e. g. P. Ariste, G. Laugaste, W. K. Matthews, etc.). On the other hand, conspicuous changes have been observed at the end of the preceding vowel. Experimental investigations have been confined merely to the production of palatograms of sharpened consonants.²

2. **Material and Methods.** In Standard Estonian palatalization may occur in connection with alveolar dentals /t' ñ l' s' (r)/. The present report deals with palatalization of Standard Estonian in functionally loaded positions, viz. mainly (1) at the end of the nominative singular forms of monosyllabic nouns, where /i/ occurred before apocope, and (2) between syllables with primary stress and following unstressed syllables in partitive plurals of such words formed by means of an /e/-allomorph (e. g. /nut'::/ 'button, (bot.)' - /nut::/ 'weeping'; /'nut'::e/ 'button, Partitive Pl.' - /'nut::e/ 'weeping, Partitive Pl.'). Special attention has been paid to differences in the acoustic features of vowels occurring in phonemically minimal pairs preceding sharpened-plain consonants (within words pro-

¹ For a thorough survey of the former interpretations of Estonian palatalization with corresponding bibliographic data, see P. Ariste, *Eesti keele palatalisatsioonist. Katselisfoneetilisi tähelepanekuid.* — *Acta Universitatis Tartuensis/Dorpatensis B L.2*, Tartu/Dorpat 1942 (1943), pp. 3—35, 50—51; G. Laugaste, *Konsonantide palatalisatsioon eesti keeles.* — *Ajaloo-Keeleteaduskonna töid* (= TRÜT, № 43), Tallinn 1956, pp. 74—88.

In addition the following papers could be noted: P. Ariste, *Eesti keele foneetika*, Tallinn 1953, pp. 77—83; W. K. Matthews, *palatalization in estonian.* — *Le Maître Phonétique*, Troisième Série, No. 100, 1953, pp. 29—32; W. K. Matthews, *Phonology of the Palatal Plosives in East-European Languages.* — *Archivum Linguisticum*, Vol. 8, Fascicule I, 1956, pp. 51—65, esp. pp. 63—64; H. Keem, *Epenteetilisest palatalisatsioonist tartu murdes.* — *ESA IV*, Tallinn 1958 (1959), pp. 145—151; I. Lehiste, *Segmental and Syllabic Quantity in Estonian.* — *American Studies in Uralic Linguistics* (= *Indiana University Publications. Uralic and Altaic Series*, Vol. 1), Bloomington 1960, pp. 21—82, esp. p. 37; R. T. Harms, *Estonian Grammar* (= *Indiana University Publications. Uralic and Altaic Series*, Vol. 12), Bloomington (The Hague, The Netherlands) 1962, p. 18.

² P. Ariste, *Hiiu murrete häälikud* (= *Acta et Commentationes Universitatis Tartuensis (Dorpatensis) B XLVII.1*), Tartu 1939; P. Ariste, *Eesti keele palatalisatsioonist*, pp. 22—35; P. Ariste, *Eesti keele foneetika*, pp. 77—83.

nounced in isolation³). It has been attempted on the basis of auditory tests to determine the role of terminal transitions in the perception of palatalization.

The conclusions presented are based on the following experimental data: segmentation of the vowels /a u i/ with a gating circuit and the determination of the quality and duration of their separate segments on the basis of auditory analysis in 150 words; visual estimation of speech wave shapes on the basis of oscillograms of the same material; energy density spectra of 160 different segments; results of the synchronous analysis of the sonagrams and sections (film speed 64 frames/sec.) of 1110 words in the syllabic nucleus of which all the 9 Estonian vowel phonemes occurred.

The latter spectrograms were obtained by means of a high-speed 52-channel dynamic sound spectrograph and its sectioner built in Tallinn by the Electronics Research Institute for the Experimental Phonetics Laboratory of the Language and Literature Institute of the Estonian S.S.R. Academy of Sciences. The frequency range of roughly 40 to 14,000 cps was analyzed. Intensity range of about 35 db. The pre-emphasis for frequencies above 1000 cps was approximately 6 db/oct. The synchronous analysis of sections and sonagrams was guaranteed by indicating the time locations of sections on the sonagrams as well as by the automatic enumeration and registration of the sections with frame counters.

Six speakers were employed in this study, four of them being men. The ages of the speakers range from 26 to 50. They work as announcers of the Estonian Broadcasting Service. They all speak perfect Standard Estonian with a Tallinn pronunciation and without any dialectal peculiarities.

In preparing the auditory tests terminal transitions of vowels (in phonemically minimal pairs) were eliminated from the magnetic tape by gating out before sharpened-plain consonants. The material was presented to the listeners in a random fashion. 95 words in all were presented for identification to 17 listeners and 1615 judgments were obtained.

3. Results.

3.1 The *total duration* of a vowel is on an average 20% greater in the case of palatalization. The average duration of a short vowel preceding over-long alveolar dentals is 166 msec in case of palatalization and 138 msec without palatalization. The lengthening referred to is the greatest in /u/ (27%) and the smallest in /i/ (11%).

3.2 As to the *durations of different segments*, it is mainly the transition between the characteristic segment and the following consonant that grows markedly longer when there is palatalization. The segmentation (a certain arbitrariness is inevitable) of short vowels in case of palatalization gave the following averages: duration of transitions between preceding consonants and characteristic segments (T_1) — 37 msec (22.5% of the total duration), duration of the characteristic segment (C) — 49 msec (29.5%), duration of transitions between the characteristic segments and following consonants (T_2) — 80 msec (48.0%). The corresponding fig-

³ The data presented in this paper are based on the analysis of word structure, in which a short stressed vowel is followed by an over-long consonant.

Generally it could be pointed out that the occurrence of palatalization in Estonian is the more conspicuous the shorter the duration of the stressed vowel and the longer the following consonant(s). See also P. Ariste, *Eesti keele palatalisatsioonist*, p. 23 *et passim*.

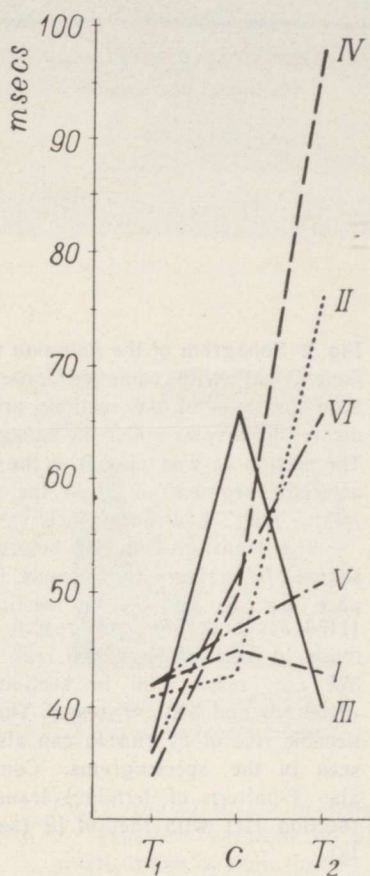


Fig. 1. Absolute durations of the characteristic segment and the transitions of different vowels before sharped-plain consonants.

The ordinate denotes the absolute duration in milliseconds. T_1 — duration of transitions occurring between preceding consonants and the characteristic segments; C — duration of the characteristic segments; T_2 — duration of transitions between the characteristic segments and following consonants. I — /a/ before plain consonants; II — /a/ before sharped consonants; III — /u/ before plain consonants; IV — /u/ before sharped consonants; V — /i/ before plain consonants; VI — /i/ before sharped consonants.

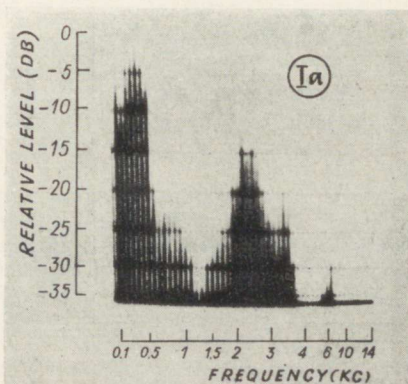
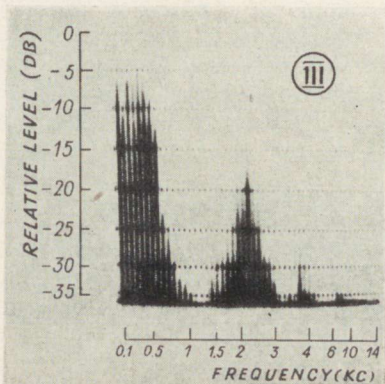
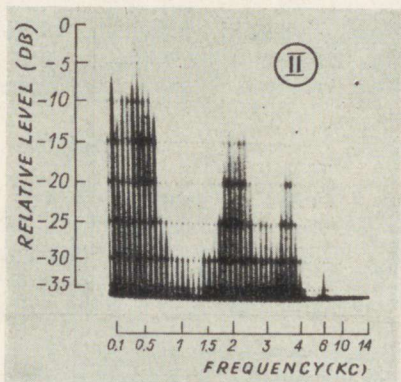
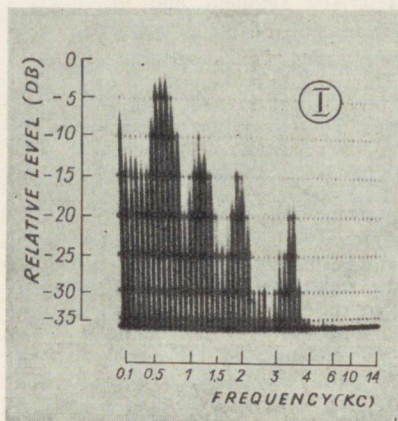
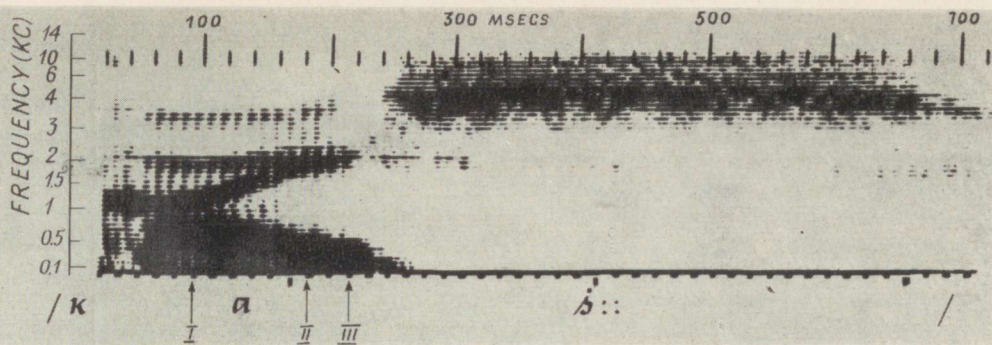


Fig. 2. Sonogram of the Estonian word /ka:/: 'cat' with some sections. The time locations of the sections are indicated by arrows under the sonogram. The section Ia was taken from the characteristic segment of /i/ in the word /pik:/: 'long'. Low bass voice.

The transitions in /a/ before the sharpened /s/ are very conspicuous. Compare, e.g. F_2 and F_1 in section I (1150 cps and 675 cps, resp.) with those in section II (1850 cps and 375 cps, resp.) and in section III (2100 cps and 300 cps, resp.). The noticeable rise of F_3 and F_4 can also be seen in the spectrograms. Compare also F-pattern of terminal transition (section III) with that of [i] (section Ia).

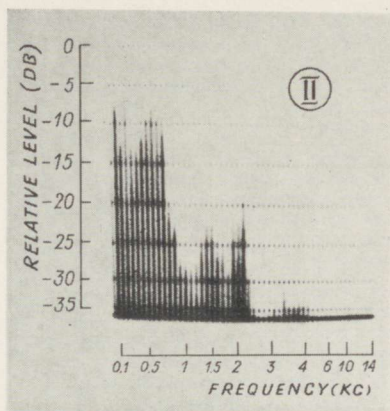
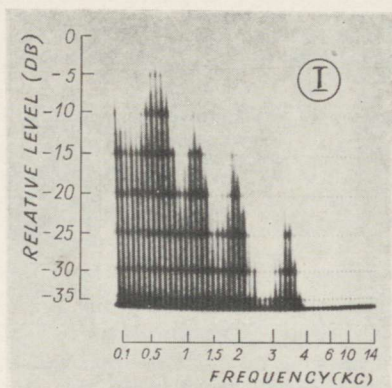
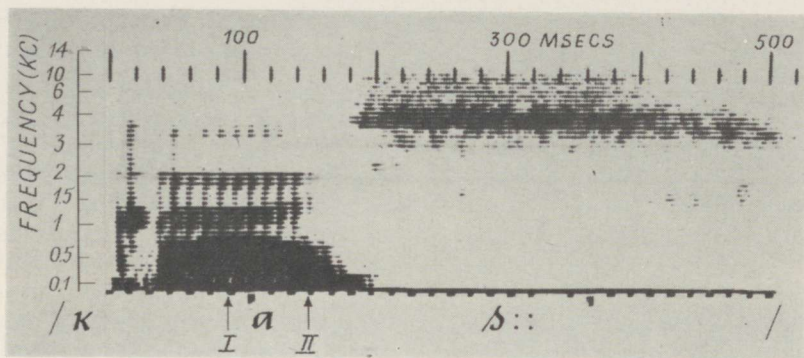


Fig. 3. Sonagram of the Estonian word /kas::/ 'if, whether'.

F-pattern variation in /a/ before plain /s/ is comparatively small. It can be seen that F_2 rises only from 1150 cps (section I) to 1400 cps (section II) and F_1 shifts downwards from 600 cps (section I) to 525 cps (section II).

ures without palatalization, however, are: $T_1 = 40$ msec (29.4%), $C = 53$ msec (38.1%), $T_2 = 45$ msec (32.5%). Thus the total duration of a vowel increases mainly due to the lengthening of the final transition.

The inherent differences of the three vowels are given in Fig. 1.

3.3 *Auditory analysis* in case of palatalization has revealed a consistent shift towards an [i]-ness in transitions following the characteristic segments of vowels (in contrast to words without palatalization). The duration of the [i]-like segments of short /a/, e. g. averages 51 msec, which is 67.1% that of the transitions following the characteristic segments (T_2) and 31.8% of the total duration (D_t). For short /u/ the corresponding figure is 45 msec, which represents 45.9% of T_2 and 24.7% of D_t .

Generally speaking, there is also a certain tendency in case of palatalization for articulation of the whole syllable to be somewhat advanced and/or closer (this tendency is the least noticeable and consistent in initial transitions).

The following are some examples of the division of vowels into seg-

ments⁴: /a/ in /kañ::/ 'plaything': [$\overset{30}{i}$ +] ($\overset{30}{[i]}$) — [$\overset{35}{a}$ +] ($\overset{35}{[a]}$) — [$\overset{35}{\varepsilon}$] ($\overset{35}{[\varepsilon]}$) — [$\overset{30}{\tilde{i}}$] ($\overset{25}{[\tilde{i}]}$) — [$\overset{25}{\tilde{i}}$] ($\overset{35}{[\tilde{i}]}$); /a/ in /kan::/ 'jug': [$\overset{30}{i}$] ($\overset{35}{[i]}$) — [$\overset{35}{a}$] ($\overset{45}{[a]}$) — [$\overset{40}{\varepsilon}$] ($\overset{35}{[\varepsilon]}$); /u/ in /kuś::/ 'hush, (interj.)': [$\overset{35}{u}$ -] ($\overset{45}{[u]}$) — [$\overset{45}{u}$ +] ($\overset{35}{[u]}$) — [$\overset{35}{\ddot{e}}$ -] ($\overset{35}{[\ddot{e}]}$) — [$\overset{30}{\tilde{i}}$ -] ($\overset{30}{[\tilde{i}]}$) — [$\overset{30}{i}$] ($\overset{40}{[i]}$); /u/ in /kus::/ 'where': [$\overset{35}{u}$ -] ($\overset{40}{[u]}$) — [$\overset{40}{u}$] ($\overset{60}{[u]}$) — [$\overset{35}{\ddot{e}}$ -] ($\overset{35}{[\ddot{e}]}$).

3.4 *Spectral analysis* in case of palatalization has shown the following consistent modifications in the spectral parameters of the transitions following the characteristic segments of vowels. The most prominent change is the marked rise in vowels of F_2 to 2000—2200 cps (to about 2200—2400 cps for front vowels) (thus the corresponding shift is the greatest in /u/). F_3 (and higher formants) also show a certain shift towards higher frequencies. There may be a concomitant rise in the relative intensity of the formants concerned. An additional reinforcement may also be sometimes observed at about 3000—3500 cps (or somewhat higher). F_1 shifts downward more conspicuously, by up to about 300—400 cps, when there is palatalization than when palatalization is lacking (this change is the greatest for /a/ and /ä/). Variations in the spectra of /i/ transitions require further investigation. A certain decrease of F_1 in the terminal transitions appears to be characteristic.⁵

The changes in spectrum structure are exemplified in Figs. 2 and 3.

3.5 In *auditory tests* words originally with palatalization and in which the [i]-like terminal transitions of vowels had been eliminated, were perceived as words without palatalization (e. g. /nut::/ instead of /nut'::/) in an average of 78.6% of cases. For different vowels the number of pertinent

⁴ The segments have been represented both in the alphabet of the International Phonetic Association as well as in the phonetic alphabet generally used in transcribing Fenno-Ugric languages (in the brackets). The numbers above each segment denote duration in milliseconds.

⁵ For data on the formant frequencies of Estonian vowels, see I. Lehiste, Segmental and Syllabic Quantity in Estonian, pp. 26—34; G. Liiv, Acoustical Features of Estonian Vowels Pronounced in Isolation and in Three Phonological Degrees of Length. — ETAT US 1962 1, pp. 63—97.

judgments was the following: in the case of /u/ — 84.7%, /a/ — 78.5%, /i/ — 74.8% (this was only to be expected in the light of the data presented above). It is also worth noting the number of corresponding judgments in the case of different consonants: /ń/ — 93.3%, /t'/ — 75.4%, (/f/) — 75.5%, /l'/ — 72.3%, and /ś/ — 54.9%. Presumably the comparatively low percentage of the latter judgments can be explained by the greater difference of spectral distribution for /ś/ and /s/, as well as by the smaller significance of vowel transitions in the perception of the indicated consonant structure.

4. Conclusion. The results of auditory tests, the relatively long duration and consistent occurrence of [i]-like terminal transitions as well as the distinct changes of spectral distribution in their structure in case of palatalization (although the acoustic structure of Estonian consonants has not been investigated) lead to the preliminary conclusion (contrary to the view held by recent investigators) that, as concerns the auditory perception of (relatively weak) Estonian palatalization, the most essential acoustic correlate of this phenomenon is the occurrence of an [i]-like transition in vowels preceding alveolar-dental consonants.

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НЕКОТОРЫЕ ДАННЫЕ ЭКСПЕРИМЕНТАЛЬНОГО ИЗУЧЕНИЯ РОЛИ ПЕРЕХОДНЫХ СЕГМЕНТОВ ГЛАСНЫХ В ВОСПРИЯТИИ ПАЛАТАЛИЗАЦИИ В ЭСТОНСКОМ ЯЗЫКЕ

В работе проанализированы акустические признаки (общая длительность, средняя абсолютная и относительная длительности, а также качественные различия переходных и характерного сегментов, изменения спектрального состава) ударных гласных, предшествующих палатализованным-непалатализованным переднеязычным согласным, в так называемых фонологических минимальных парах, исходя из слухового (при помощи сепаратора), осциллографического и спектрального анализов (с помощью 52-канального динамического спектрографа с устройством для получения мгновенных спектров). Целью серии опытов по восприятию являлось исследование возможных изменений в восприятии палатализации в результате удаления (при помощи сепаратора) с магнитной ленты терминальных переходных сегментов гласных, предшествующих палатализованным-непалатализованным согласным. Выводы основываются на анализе произнесений шести дикторов, в совершенстве владеющих эстонским литературным языком в таллинском его варианте без каких-либо диалектных особенностей.

Результаты опытов по восприятию, сравнительно большая длительность и последовательное наличие [i]-образных терминальных переходных сегментов, а также значительные изменения спектральной дистрибуции в их акустической структуре привели автора к первоначальному общему выводу, что более существенным акустическим коррелятом слухового восприятия (сравнительно слабой) палатализации в эстонском языке следует считать наличие [i]-образных терминальных переходных сегментов гласных, предшествующих переднеязычным согласным.