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ON QUALITATIVE FEATURES OF ESTONIAN STRESSED MONOPHTHONGS OF THREE PHONOLOGICAL DEGREES OF LENGTH

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INTRODUCTION

Quantity and Quality

In many languages in whose structure quantity plays an important role, other essential inseparable features are often associated with the purely durational distinctions between long and short vowels. Such features are primarily qualitative in character and they may vary greatly from one language to another. The essence and general trend of qualitative distinctions in different languages may also vary or even be entirely contrary. There are some languages in which no quantitative and qualitative correlations have been registered.

In German, for instance, with its two phonological degrees of length, the closeness of articulation is generally greater in the case of long vowels than in that of the corresponding short vowels (a *close/open* opposition). A greater degree of muscular tension of the organs of speech has also been pointed out in the articulation of long vowels (a *tense/lax* opposition).[1] Complexes of length and tamber also serve to distinguish corresponding pairs of vowels in English. In this connection one must refer to a certain diphthongicity of long vowels: a diphthongoid begins with a more open variety of a sound and gradually moves towards a narrower variety.[2] In Swedish, Danish and Hungarian quantitative differences are connected with appreciable qualitative peculiarities. It is interesting to note that in Danish and Hungarian the qualitative difference of the sound *a* occurring in different degrees of length possesses a completely contrary tendency and character than in the languages referred to earlier: long *a* is a front vowel, whereas short *a* is a

[1] For details, see W. Viëtor, Die Aussprache des Schriftdeutschen. Leipzig, 1909; Elemente der Phonetik des Deutschen, Englischen und Französischen. Leipzig, 1914, pp. 78 ff., 322 ff.; O. Jespersen, Lehrbuch der Phonetik. Leipzig, 1920, pp. 147 ff., 183 ff.; Th. Siebs, Deutsche Bühnenaussprache. Bonn, 1920, p. 35 ff.; B. Malmberg, Die Quantität als phonetisch-phonologischer Begriff. "Lunds Universitets Årsskrift", N. F. Avd. 1, Bd. 41, 1944, No. 2, p. 37 ff.; R.-M. S. Heffner, General Phonetics. Madison, The University of Wisconsin Press, 1949, p. 96 ff.; D. Jones, The Phoneme: Its Nature and Use. Cambridge, 1950, pp. 19, 30, 129, 171, 172; O. Essen, Allgemeine und angewandte Phonetik. Berlin, 1957, p. 60 ff.; H.-H. Wängler, Atlas deutscher Sprachlaute. Berlin, 1958, pp. 35—38, Plates 115—129; М.-И. Матусевич, Введение в общую фонетику. Москва, 1959, pp. 74 ff., 82 ff; Л. Р. Зиндер, Общая фонетика. Издательство Ленинградского университета, 1960, p. 208 ff.

[2] See W. Viëtor, Elemente der Phonetik des Deutschen, Englischen und Französischen, pp. 81 ff., 324 ff.; O. Jespersen, Lehrbuch der Phonetik, pp. 148 ff., 184 f., B. Malmberg, Die Quantität als phonetisch-phonologischer Begriff, p. 37; Ch. K. Thomas, An Introduction to the Phonetics of American English. New York, 1947, p. 47 ff.; R.-M. S. Heffner, General Phonetics, p. 96 ff.; D. Jones, The Phoneme: Its Nature and Use, esp. pp. 17, 29, 30, 127—129, 166—170; An Outline of English Phonetics. Cambridge, 1956, p. 63 ff.; М. И. Матусевич, Введение в общую фонетику, p. 82 ff.

back vowel.[3] Long and short vowels in Singhalese, for instance, differ only slightly in their quality.[4]

In French the phonological opposition of short and long vowels is very limited. The length of most qualitatively different vowels depends on the phonetic context in accordance with certain rules.[5]

In addition to the languages mentioned above there are a number of other languages where vowels are contrasted as to quantity and quality. On the other hand, there are also some languages where significant distinctions are believed to be rendered merely by variation of the degrees of length unattended by any other features. Such languages are, e. g., Japanese, Finnish, Somali, Kikuyu and Luganda.[6]

The problem of what is relevant in terms of the perception of quantity and of which features are to be regarded as merely concomitant and inessential phenomena (epiphenomena, "Begleiterscheinungen") is highly complicated and has given rise to several different hypotheses based on experimental data. Among the essential features mentioned in this connection one finds: a characteristically different intonation[7], different modes of contact between a vowel and a following consonant ("*loser/fester* Anschluss")[8], prolongability and improlongability ("Dehnbarkeit/Nichtdehnbarkeit"), the different relative duration of the so-called "characteristic segment" and transitional segments[9], a different degree of tension in the vocal cords[10], different degrees of the occurrence of coarticulation[11], etc.

Literature Available on the Quantitative System of Estonian

The quantitative system of Estonian is unique in the respect that one has here three phonologically relevant degrees of length for vowels as well as consonants (the number of phonetic degrees of length is considerably greater). This accounts for the prolonged and

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[3] B. Malmberg, Die Quantität als phonetisch-phonologischer Begriff, pp. 37, 38; D. Jones, The Phoneme: Its Nature and Use, pp. 30, 170, 171; B. Malmberg, Distinctive Features of Swedish Vowels: Some Instrumental and Structural Data. For Roman Jakobson. The Hague, 1956, pp. 316—321.

[4] D. Jones, The Phoneme: Its Nature and Use, pp. 28, 29, 160, 161.

[5] For details, see G. Nicholson, A Practical Introduction to French Phonetics. London, 1909, pp. 175, 176; L. E. Armstrong, The Phonetics of French. London, 1932, pp. 151—153; P. Passy, Les Sons du Français. Paris, pp. 62, 63; W. Viëtor, Elemente der Phonetik des Deutschen, Englischen und Französischen, pp. 89 ff., 326 ff.; O. Jespersen, Lehrbuch der Phonetik, pp. 147 ff., 187 ff.; D. Jones, The Phoneme: Its Nature and Use, pp. 16, 121, 130, 131; М. И. Матусевич, Введение в общую фонетику, p. 82 ff.; Л. Р. Зиндер, Общая фонетика, p. 208 ff.

[6] D. Jones, The Phoneme: Its Nature and Use, pp. 16, 120, 121, 160; A. Sovijärvi, Über die phonetischen Hauptzüge der finnischen und ungarischen Hochsprache. Wiesbaden, 1956, p. 8.

[7] M. Durand, Durée phonétique et durée phonologique. Proceedings of the Third International Congress of Phonetic Sciences. Ghent, 1939, pp. 261—265; Essai sur la nature de la notion de durée vocalique. "Travaux du Cercle Linguistique de Prague" VIII, 1939, pp. 43—50; Voyelles longues et voyelles brèves. Paris, 1946, p. 41 ff.

[8] E. Fischer-Jørgensen, Objektive und subjektive Lautdauer deutscher Vokale. "Archiv für vergleichende Phonetik" IV, 1940, pp. 1—20; Neuere Beiträge zum Quantitätsproblem. "Acta Linguistica" II, 1940—1941, pp. 175—181. It is well known that the doctrine of the modes of contact between neighbouring sounds originated with E. Sievers, Grundzüge der Phonetik. Leipzig, 1885, p. 139 ff.

[9] E. Richter, Länge und Kürze. «Archiv für vergleichende Phonetik» II, 1938, pp. 12—29.

[10] J. Forchhammer, Länge und Kürze. «Archiv für vergleichende Phonetik» III, 1939, pp. 19—26; R.-M. S. Heffner, General Phonetics, p. 96 ff.

[11] J. Forchhammer, Länge und Kürze. For a comprehensive discussion of this problem, see B. Collinder, Über den begriff der quantität mit besonderer rücksicht auf die lappische sprache. "Journal de la Société Finno-ougrienne" XLII, Helsinki, 1928, pp. 1—24; B. Malmberg, Die Quantität als phonetisch-phonologischer Begriff.

continuing interest taken by many outstanding phoneticians and phonologists in this complicated problem. The views of specialists have been extremely divergent as regards quantity in the Estonian language. The number of phonologically relevant degrees of length still remains a subject of controversy. Studies of the nature of quantity in the light of experimental data have been quite haphazard, scanty and insufficient.

The first discussion of the three essential degrees of length in Estonian dates back to M. Weske.[12] It was also in the 19th century that the existence in Estonian of four relevant degrees of length was first suggested. Such a view was held by F. J. Wiedemann[13] and O. Kallas[14] (the latter, it is true, did so in the case of the Lutsi dialect). The next to analyze the phonetic facts of the quantity system of Estonian were L. Kettunen[15] and E. Lagercrantz[16]. B. Collinder produced a diachronic study of quantity in Estonian.[17] The most recent attempt to distinguish four degrees of length in Estonian was made by E. Polivanov, who also drew attention to the distinctive intonation of the degrees of length.[18] N. S. Trubetzkoy, proceeding from the well-known thesis of the Prague school of phonology stating that there cannot be more than two phonologically contrasted degrees of length in any language[19] and relying on the unsound linguistic material of E. Polivanov, has claimed that the quantitative system of Estonian is based on only two phonological degrees of length, the other degrees of length being distinguished by an intonation of a phonological character.[20] P. Ariste has repeatedly stressed the existence in Estonian of three phonological degrees of length, and has made a number of phonetic measurements in this field.[21] Various problems connected with quantity have also been dealt with by E. Põldre[22] and Õ. Sõster[23]. The existence of three phonological degrees of length

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[12] M. Weske, Untersuchungen zur vergleichenden Grammatik des finnischen Sprachstammes. Leipzig, 1872, pp. 6—18.

[13] F. J. Wiedemann, Grammatik der ehstnischen Sprache. St.-Pétersbourg, 1875, pp. 136, 137.

[14] O. Kallas, Lutsi Maarahvas. «Suomi», Vol. III, No. 12, Helsinki, 1895.

[15] L. Kettunen, Lautgeschichtliche untersuchung über den kodaferschen dialekt. «Mémoires de la Société Finno-ougrienne» XXXIII, Helsinki, 1913, esp. p. 21 ff.; L. Kettunen, Viron kielen äännehistoria. Helsinki, 1917; Edition II — Eestin kielen äännehistoria, «Suomalaisen Kirjallisuuden Seuran Toimituksia» CLVI, Helsinki, 1929.

[16] E. Lagercrantz, Strukturtypen und Gestaltwechsel im Lappischen. «Mémoires de la Société Finno-ougrienne» LVII, 1927, esp. pp. 27—44.

[17] B. Collinder, Über den finnisch-lappischen Quantitätswechsel. "Uppsala Universitets Årsskrift", 1929, esp. pp. 21—51, 72—80.

[18] Е. Д. Поливанов, Введение в языкознание для востоковедных вузов. Ленинград, 1928, pp. 197—202; E. D. Polivanov, Review of "Remarques sur l'évolution phonologique du russe comparée à celle des autres langues slaves", by Roman Jakobson, "Slavia" XI, 1932, pp. 145, 146.

[19] N. S. Trubetzkoy, Die phonologischen Grundlagen der sogenannten «Quantität» in den verschiedenen Sprachen. Scritti in onore di Alfredo Trombetti, Milano, 1938, pp. 155—174.

[20] N. S. Trubetzkoy, Grundzüge der Phonologie. «Travaux du Cercle Linguistique de Prague» VII, Prague, 1939, pp. 178, 189, 190.

[21] P. Ariste, Eesti sulghäälikud *k, p, t* ja *b, d, g*. «Eesti Keel» XII, Tartu, 1933, pp. 73—82, 170—181; A Quantitative Language. Proceedings of the Third International Congress of Phonetic Sciences. Ghent, 1939, pp. 276—280; Hiiu murrete häälikud. Tartu, 1939; Eesti keele hääldamine. Tartu, 1939, pp. 82—89; Hiiu murrete häälikute kvantiteedist. Tartu, 1941; Eesti keele kvantiteediküsimusi. Foneetilisi probleeme eesti keele alalt. Eesti NSV Tartu Riikliku Ülikooli toimetised, Filoloogilised teadused 3, Tartu, 1947, pp. 3—19; Eesti keele foneetika. Tallinn, 1953, esp. pp. 89—95.

[22] E. Põldre, Intonatsiooni, kvantiteedi ja dünaamilise rõhu suhteist eesti keeles. «Eesti Keel» XVI, 1937, pp. 164—183.

[23] Õ. Sõster, Teise silbi poolpikk vokaal eesti ühiskeeles. «Eesti keel» XVII, 1938, pp. 213—223.

in Estonian has been recognized by M. Durand, A. Sauvageot, B. Malmberg, D. Jones.[24]

A new and lively international discussion of quantity in Estonian was launched by L. Posti[25], who sought once again to prove (although by means of another set of arguments) that there are only a short and a long phonological degree of length or two chronemes in Estonian. L. Posti regards the long and over-long degrees of length to be allochrones of the phonologically long degree of length, consequently he considers them to be an epiphenomenon caused by the semi-long or short vowel in the second syllable (the opposition *long/short* in phonology). A positive feature of L. Posti's approach is that he regards the duration of the whole syllable and not that of a single sound as essential from the viewpoint of the quantitative system.

The fairly numerous articles of the subsequent period may be summarized as a reaction against the views of L. Posti just referred to. The untenable character of L. Posti's arguments has been pointed out by B. Collinder, J. Mägiste, A. Raun.[26] B. Collinder has also made a comparison of the quantitative systems of Estonian and Lapp, whereas A. Raun has analyzed morphophonemic alternations in Estonian. In a more recent article A. Raun has pointed out briefly that the problem of contact features arises in connection with quantity in Estonian.[27] H. Must has recently studied the duration of sounds belonging to different degrees of quantity.[28] It appears, unfortunately, that this author has likewise drawn chiefly on isolated words for her material. Some references to quantity in Estonian have been made by V. Tauli[29] in the course of a polemic with B. Collinder[30]. Before this, V. Tauli had already given a diachronic account of the quantitative system in Estonian.[31]

R. T. Harms's structuralistic analysis reveals that he actually recognizes only

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[24] M. Durand, Durée phonétique et durée phonologique, pp. 263, 264; Voyelles longues et voyelles brèves, pp. 14, 24, 31, 32, 78—90, 140, 164. The present writer has had an opportunity of getting acquainted with A. Sauvageot's views as expressed in a report delivered at the *Société de Phonologie* in 1938, only from a review by V. Niilus, Eesti keele vältevaheldus prantsuse fonoloogide ees. «Eesti Keel» XVII, 1938, pp. 159, 160; B. Malmberg, Die Quantität als phonetisch-phonologischer Begriff, pp. 25, 36, 42, 52; D. Jones, Chronemes and Tonemes. "Acta Linguistica" IV, 1944, p. 5; The Phoneme: Its Nature and Use, pp. 52, 119, 127, 132, 133, 143, 172, 173.

[25] L. Posti, On Quantity in Estonian. "Journal de la Société Finno-ougrienne" XIV, 1948—1950, pp. 1—14$_2$.

[26] B. Collinder, Three Degrees of Quantity. "Studia Linguistica" V, 1951, pp. 28—43; J. Mägiste, Några ord om den estniska kvantiteten. "Meddelanden från Seminarierna för slaviska språk, jämförande språkforkning och finsk-ugriska språk vid Lunds Universitet" I, Lund, 1951, pp. 5—12; unfortunately, the present writer has not been able to see the article in the original. The views expressed in it have been sufficiently summarized, however, in the next article referred to below as well as in R. T. Harms's A Descriptive Grammar of Estonian. A Dissertation Submitted to the Faculty of the Division of the Humanities in Candidacy for the Degree of Doctor of Philosophy. The University of Chicago, Department of Linguistics. Chicago, Illinois, March, 1960, pp. 177, 178; A. Raun, On Quantity in Estonian. "Studia Linguistica" VIII, 1954, pp. 62—76.

[27] A. Raun, Word Stress in Estonian. "Lingua" VIII, 1958, pp. 349—355, esp. p. 354.

[28] H. Must, Distinctive Duration of Speech Sounds in Estonian. "Finnisch-ugrische Forschungen" XXXIII, 1958, pp. 146—163; Duration of Speech Sounds in Estonian. "Orbis" VIII, No. 1, 1959, pp. 213—223.

[29] V. Tauli, A Chapter on Estonian Quantity. "Phonetica" 3, No. 2/3, 1959, pp. 109—117.

[30] B. Collinder, Survey of the Uralic Languages. Stockholm, 1957, pp. 137—139.

[31] V. Tauli, The Origin of the Quantitative System in Estonian. "Journal de la Société Finno-ougrienne" LVII, 1957, p. 6 ff.

two phonological degrees of quantity in Estonian.[32] R. T. Harms phonemicizes long, over-long, and, in some cases, also so-called semi-long vocoids and contoids as geminate clusters of phonemes. R. T. Harms regards different phonological stress as the only distinctive feature of the long and the over-long degrees of length. Long geminate clusters are brought about by plain stress, i. e. stress on the first component of the cluster, whereas the over-long degree of length is due to postposed stress, i. e. stress on the second component of the cluster. Hence, in Harms's treatment the phonologically long degree of length comprises both the long and over-long degrees of quantity (in our sense). As regards the quality of vowels of different degrees of length, however, in his list of allophones, Harms has provided the phonologically long (in his sense) *i, ü, u, e, ę* with a diacritic mark indicating a closer degree of articulation.[33] Thus the author states that phonologically long and over-long vowels (in our sense) are of the same quality. It also follows that *ö, o, a, ä* in three phonological degrees of length are of the same quality. The author's assumptions regarding intonation patterns connected with quantity appear likewise to be improbable. R. J. Harms's treatment of quantity in Estonian does not seem to be in agreement with the facts of the language.

In a recent paper I. Lehiste[34] recognizes three phonological degrees of length in Estonian, discussing them from the standpoint of the duration of single sounds and syllables. The attendant intonation has also been investigated to a certain extent. I. Lehiste maintains that quantity does not affect the quality of vowels: "Neither stress nor segmental quantity has any significant influence on vowel quality."[35] The following view expressed by the author is highly debatable: "It appears, furthermore, that the mora has a physical reality not only in terms of subjectively experienced duration, but also in terms of intensity. ... three-mora vowels have three clearly discernible peaks of energy, vowels of two morae have two such peaks, and one-mora vowels have, as a rule, only one energy peak."[36]

In a brief summary of the preceding, it should be pointed out that the majority of researches into quantity in Estonian have been concerned mainly with the theoretical problem of the number of phonologically relevant degrees of length in the language. The number of such degrees as distinguished by different authors has been four (Wiedemann, Kallas, Polivanov), two (Trubetzkoy, Posti, Harms) or three (other authors).

There are comparatively few experimental investigations. Attention has centred primarily on the duration of sounds as measured on the basis of kymographic recordings (Kettunen, Lagercrantz, Ariste, Durand, Sõster; Must and Lehiste have used spectrograms for the same purpose), and the results obtained have varied considerably. Observations regarding intonation have been quite contradictory.[37] The principal shortcoming of these studies, in our opinion, is that the phenomena involved have been investigated in isolated words and not in concrete contexts (only I. Lehiste, and, to a certain extent, H. Must, have made use of contextual material). P. Ariste

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[32] R. T. Harms, A Descriptive Grammar of Estonian, p. 33 ff.
[33] R. T. Harms, A Descriptive Grammar of Estonian, p. 34.
[34] I. Lehiste, Segmental and Syllabic Quantity of Estonian. "American Studies in Uralic Linguistics", Indiana University Publications, Uralic and Altaic Series I, 1960, pp. 21—82.
[35] Ibid., p. 25.
[36] Ibid.
[37] Cf. N. S. Trubetzkoy, Grundzüge der Phonologie, p. 178; E. Põldre, Intonatsiooni, kvantiteedi ja dünaamilise rõhu suhteist eesti keeles; P. Ariste, A Quantitative Language, p. 280; Eesti keele hääldamine, p. 88; Eesti keele kvantiteedi-küsimusi, p. 10; Eesti keele foneetika, p. 99; B. Malmberg, Die Quantität als phonetisch-phonologischer Begriff, p. 42; M. Durand, Voyelles longues et voyelles brèves, pp. 79—90; R. T. Harms, A Descriptive Grammar of Estonian, p. 14; I. Lehiste, Segmental and Syllabic Quantity in Estonian, pp. 60—62.

has taken X-ray photographs of single sounds pronounced in isolation [38] and has made an extensive study of sounds by means of the palatographic method.[39] Correlations of quality and quantity within the phonetic structure of Estonian have not been systematically studied by experimental methods. On the whole, the opinion has hitherto prevailed that vowels in the three phonological degrees of length differ very slightly or are quite identical as regards their quality.[40]

In this paper we should like to present some of our own observations concerning the qualitative features of Estonian stressed monophthongs of three phonological degrees of length. This article is confined to an experimental-phonetical account of the articulatory or genetic aspect of vowels on the basis of röntgenographic and palatographic material as well as films of the external organs of speech.

METHODS AND MATERIALS

Röntgenography

Conditions of röntgenography. X-ray photographs were taken at the Republican Tuberculosis Dispensary in Tallinn. The X-ray apparatus used was Model РУД 110-150-1, of 1956, equipped with a 10БДМ110 rotating tube. During the whole cycle of experiments the following technical conditions were strictly observed: distance of X-ray tube from X-ray film — 92 cm; exposure time — 0.2 sec.; 87 kV; 150 mA. The central ray was directed through the crown of the first upper molar. The median plane of the subject was parallel with the X-ray film. The head tilt was fixed by means of a specially designed stand [41]. This enabled the required position of the subject to be reproduced in every consecutive series of experiments. A mixture of *barium sulfuricum* and water was used as contrasting substance. A narrow strip of this mixture was drawn with a brush along the middle of the surface of the tongue, the palate and the upper and lower lips of the subject. This procedure was repeated after every one or two experiments in order to avoid diffusion of the barium in the oral cavity (such diffusion interferes with the accurate determination on the X-ray negative of contours situated on the median plane).

The distance between the median plane of the subject and the X-ray film was about 21 cm. The left-hand *angulus mandibulae* of the subject was on an average 4 cm nearer, and the right-hand one 4 cm farther away, than the median plane. Consequently the actual dimensions of the organs situated on the median plane were enlarged about 1.30 times on the X-ray negative. Due to the conical emission of X-rays, the enlargement on the X-ray negative of the image of the contours of organs nearer to the X-ray film than the median plane, is slightly smaller, whereas the enlargement of the projection of contours farther away from the median

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[38] P. Ariste, Eesti keele foneetika, p. 33 ff.; Eesti ühiskeele õ-st. Foneetilisi probleeme eesti keele alalt. Eesti NSV Tartu Riikliku Ülikooli toimetised, Filoloogilised teadused 3, 1947, pp. 20—38.

[39] P. Ariste, Hiiu murrete häälikud; Eesti keele foneetika, as well as the other works mentioned above. L. Kettunen has made palatograms of the sounds of the dialect of Kodavere. The first attempt at a description of Estonian sounds was made by A. Saaberk, Eesti foneetika alged. Tallinn, 1920.

[40] See P. Ariste, Hiiu murrete häälikud, pp. 33, 47, 52, 62, 73, 76, 91, 107, 118, 119, 126, 127, 133; Eesti keele foneetika, pp. 58, 59, 62, 94; D. Jones, The Phoneme: Its Nature and Use, pp. 172, 173. R. T. Harms, A Descriptive Grammar of Estonian, p. 34; I. Lehiste, Segmental and Syllabic Quantity in Estonian, p. 25.

[41] See G. Liiv, Foneetika uusi suundi ja meetodeid. «Keel ja Kirjandus», Tallinn, 1960, No. 8, pp. 482—490, esp. pp. 487, 488.

plane in relation to the film is bigger than the average on X-ray photographs. The maximum range of enlargement is about 1.23—1.34, respectively. The initial size of the negative plates of X-ray films was 24 × 30 cm.

Synchronized tape recordings were made of the material being X-rayed. For this purpose a special microphone key was constructed. The key turned on the microphone which was attached to the stand regulating the head tilt of the subject, at the same time as the X-ray tube was switched on, i. e. simultaneously with the beginning of the exposure of the X-ray film. We used a МАГ-8 tape recorder, "Agfa" Type-C tape, a recording speed of 381 mm/sec., and a microphone of Type МД-55, which was held at a distance of about 12 cm from the subject's mouth. The first auditive analysis of the X-rayed material was undertaken immediately after recording. Whenever it was found that the so-called culminational or characteristic phase of the vowel had not been caught, the experiment was repeated. After the tape had been edited, it was possible to carry out an auditive analysis of the acoustic quality of only such a segment as corresponded to a given X-ray photograph.

The considerable amount of noise produced by the rotating tube did not permit us to obtain recordings of very high fidelity. Consequently we did not find it expedient to subject the recorded material to acoustic analysis. The complex method we have employed has the following advantages: (1) it enables one to ascertain fairly exactly the phase of the articulation of a vowel to which a given X-ray photograph corresponds, and (2) it makes it possible to check the acoustic quality of X-rayed segment. When a certain movement of the organs of speech at the time of exposure was noticed in the X-ray photograph, the experiment was repeated at a subsequent sitting.

The experiments were carried out during a period covering March—June 1959. The series of experiments were repeated after intervals of one month. Not more than 6—10 X-ray photographs were made of one subject at each sitting. A total of well over 200 X-ray photographs were taken. The present work is based on the best 113 of these photographs.

Röntgenogram tracings. The röntgenograms have been traced on transparent paper from röntgen negatives on an electrically highly illuminated and electrically cooled viewing box in a darkened room. As the configuration of the vocal tract in the median plane is of particular importance in characterizing articulation, the contours of the median sagittal cross-section of the organs of speech have been traced with a continuous line. Those parts of the organs of speech which are of interest from the standpoint of articulation, but through which the median plane does not pass directly (or whose more distinct contours do not correspond to the cross-section), have been marked with a broken line. A dotted line has been used to designate parts of those organs of speech whose contours cannot be conclusively ascertained from the X-ray negative for technical reasons (occasionally the velum, the uvula, the sinus of larynx). Consequently, in cases where two (more rarely three) contours of the tongue have been traced, a continuous line marks the median of the tongue, and a broken line (or lines), the projection of the side (or sides) of the tongue. Such a grooved shape of the tongue is especially characteristic of Subject V, the body of whose tongue is particularly big. A peculiarity of the organs of speech of Subject I is his very long velum, which results in a certain bulge when sounds are articulated.

The röntgenograms to be found in this work have been reduced in size in the ratio 2 : 1. To ensure objectivity and precision there has been no simplification or adaptation of either röntgenogram when producing a superimposed röntgenogram. In making the latter, the outlines of the palate and the front upper teeth (naturally of the same subject), i. e. of the passive and immobile organs, have been scrupulously superimposed. This means that different or identical positions of

the active and mobile organs are clearly visible and can be easily analyzed. In some of the superimposed röntgenograms one can observe a certain divergence in the outlines of the vertebrae. This may be due in part to a slight deviation of the direction of the central ray, since the enlargement of the image towards the sides of a X-ray negative is the greater (owing to the conical emission of X-rays), the farther the image is situated from the area towards which the central ray is directed. The small divergence in the outlines of the vertebrae may also be accounted for by a slight change in the head tilt in relation to the spine or the X-ray film cassette. Such accidental slight discrepancies are probably inevitable, and we hope that they have not affected the results of our work to any appreciable extent.

In the superimposed röntgenograms the position of the organs of speech when articulating the third phonological degree of length of a vowel has been marked in black; their position in the articulation of the second phonological length of the same vowel has been indicated in red. The same principle has been applied when comparing the articulation of different monophthongs. The present writer has also made a number of measurements on the basis of the röntgenograms analyzed, but the data obtained from these measurements are not discussed in this paper.

Language material and informants. This study of the articulation of Estonian stressed monophthongs is based on words pronounced by the informant not separately, but as identical parts of a sentence in declarative and affirmative sentences in the indicative mood (as the first words that do not carry the logical sentence stress). Vowels of the phonologically long and over-long degrees of length in open syllables and in identical consonantal environments have been investigated (the long and over-long phonological degrees of length are marked with the numbers II and III):

saade (II) 'transmission, *Nominative Sg.*' — saadu (III) 'hayrick, *Illative Sg.*',
poosi (II) 'pose, *Genitive Sg.*' . . . . . — poosi (III) 'pose, *Partitive Sg.*',
puuda (II) 'pood, *Genitive Sg.*' . . . . — puuda (III) 'pood, *Partitive Sg.*',
(ei) reeda (II) 'betray, *Present Indicative Negative*' — reede (III) 'Friday, *Nominative Sg.*',
piida (II) 'jamb (of a door, etc.), *Genitive Sg.*' — piide (III) 'tooth of a comb, *Genitive Pl.*',
põõsas (II) 'bush, *Nominative Sg.*' . . . — põõsas (III) 'bush, *Inessive Sg.*',
pääsu (II) 'escape, *Genitive Sg.*' . . . . — pääsu (III) 'escape, *Partitive Sg.*',
pööra (II) 'toggle, *Genitive Sg.*' . . . . — pööra (III) 'toggle, *Partitive Sg.*',
püüri (II) 'pillow-case, *Genitive Sg.*' . . — püüri (III) 'pillow-case, *Partitive Sg.*'.[42]

This study has been limited to an investigation of Standard Estonian, mainly as it is spoken in Tallinn. Six informants have been employed, of whom I, IV, V and VI are men, whereas II and III are women. The ages of the informants range from 27 to 34. All six informants speak perfect Standard Estonian without any dialectal idiosyncrasies. On the basis of their extraction, one might have expected to find some influence of the Southern-Estonian dialects in the case of Subject I, some Viru dialect characteristics in Subject III, and some features of the dialect of Mulgi in Subject VI. Neither the röntgenograms nor auditive analysis, however, reveal any dialectal features. The other informants were born in and have been permanent residents of Tallinn. Röntgenograms covering the entire program outlined in this work were obtained from the first five informants, but only in part from Subject VI.

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[42] In the last two words the vowel of the stressed syllable was likewise pronounced as a long (resp. an over-long) monophthong, without diphthongizing it, as is often the case with the pronunciation of long and over-long *ü*.

Palatography

Palatograms were made of monophthongs in three phonological degrees of length. The traditional method was used. The palatogram blanks employed represent the surface of the palate and not the vertical projection of the latter. An additional device suggested by D. Jones was also used.[43] The distance between the jaws was kept constant, thus avoiding any influence of the position of the jaws upon that of the tongue. To ensure this while making palatograms, the end of a pencil was held firmly between the front teeth. Palatograms obtained in this way have been marked with an asterisk. Such palatograms have frequently revealed peculiarities in the articulation of vowels due to differences in degrees of length more distinctly. Moreover, in that case there seem to be less variations within the limits of the "same articulation".

In making palatograms of the vowels studied, we have used words whenever possible, and also meaningless combinations of syllables. In doing this the following principles have been observed: (1) a vowel may be studied in different degrees of length only in an identical consonant environment, (2) the latter may consist only of bilabials, (3) the vowel of the second syllable may only be *a*. By way of illustration, such cases as the following have been contrasted: *pim̄ — pīmà — pîma, pom̄ — pōmà — pôma,*[44] etc. Monosyllabic combinations have been used in making palatograms of short vowels on the grounds that words of this form occur more frequently in the language. The experiments showed that palatography does not register any appreciable articulative difference between a short vowel pronounced in a closed and an open syllable.

Four subjects, A, B, C and D, were employed in the course of this work. Subject A is the same person as Subject I and Subject C the same as Subject III of the röntgenographic series of experiments. Subjects B and C are of the same age group as the other informants. Their pronunciation is also in complete accordance with the orthoëpic norm of Standard Estonian.[45] 5—7 palatograms of each example were made according to the traditional method in the case of all the informants (7 throughout in the case of B and C). An additional 3 (whenever necessary, even more) palatograms were made according to the procedure recommended by D. Jones. A total of 1205 palatograms were produced, 823 by the traditional method and 382 by means of the supplementary method referred to above. These numbers may be subdivided according to persons as follows: A — 153 + 76 = 229; B — 294 + 126 = 420; C — 252 + 108 = 360; D — 124 + 72 = 196. The palatograms of the same example made by each person were transferred to the same blank. In doing this the average of the variations was also traced and the extreme deviations indicated. The tracings that showed the average values of the articulation of the three different phonological lengths of each vowel were then concentrated on one blank. It has thus been possible in this work to give a selection of summary palatograms showing the average articulation of the three phonological degrees of length of vowels. The continuous line in such summary palatograms marks the outlines of the contact area when a vowel of the first degree of length is articulated, the long degree of length is indicated by the broken line, and the over-long degree of length by the dotted line. The scale is 1 : 2. Differences in the shape of the palate in the case of different subjects are given in the form of the measurements AB, DE and BB′, the meaning of which becomes apparent in the drawing below (representing the palate of Subject B).

It is well known that the size and character of the linguo-palatal contact area depend largely on the shape of a person's palate. The pertinent data according to persons are as follows: Subject A — AB = 35.5 mm, DE = 44 mm, BB′ = 20.5 mm;

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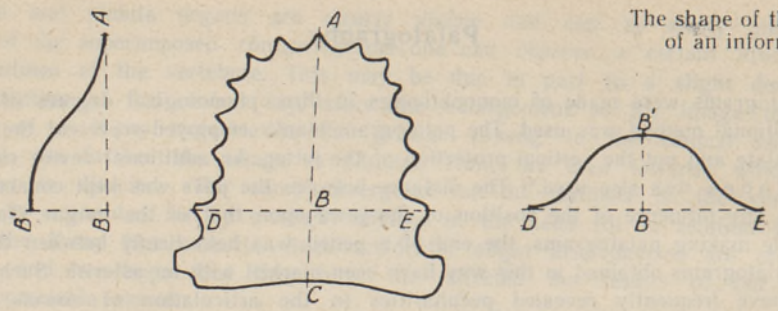
[43] D. Jones, An Outline of English Phonetics, pp. 30, 31.

[44] See note on marks designating separate degrees of length, p. 50.

[45] Judging by their place of origin, one might presuppose some minor dialectal influences from the Western Estonian and Northern Tartu dialect areas, respectively.



The shape of the palate of an informant.

Subject B — AB = 35.5 mm, DE = 48 mm, BB′ = 14.5 mm; Subject C — AB = 32 mm; DE = 40 mm, BB′ = 16 mm; Subject D — AB = 41 mm, DE = 42 mm, BB′ = 19 mm.

The variational-statistical investigation of the phenomena dealt with does not lie within the scope of the present paper.

Filming the External Organs of Speech

The purpose of the filming of the external organs of speech was to observe the position of the lips in articulating different vowels, on the one hand, and in pronouncing the phonologically contrasted degrees of length of the same vowel, on the other. The dynamics of labial articulation were also studied, although this question has not been dealt with in this paper. Front views and profile views were taken simultaneously. The rate of exposure was 25 pictures a second. Synchronized tape recordings of the experimental material were made in the course of the filming. These tape recordings served to make oscillographic recordings. Measurements of the durational relationships of words, sounds and pauses in the latter enabled us to ascertain those pictures which interpreted the position of the lips in the articulation of the culminational phase of individual sounds or the dynamics of the labial articulation corresponding, for instance, to the pronunciation of distinct segments of a certain vowel. It is from these pictures that our photographic enlargements have been made. Such words were utilized as experimental material where the three phonological degrees of length of the same vowel occur between the same alveolar consonants (so as to avoid the coarticulative influence of labial sounds). The words selected were dissyllabic, the first syllable being an open one. The words were pronounced in context and they occupied a more or less identical position within sentences (analogical to the type of sentences used in the series of röntgenographic experiments). Three informants were filmed, two of them being identical with Subjects I and II, respectively, of the series of röntgenographic experiments. The third informant is identical with Subject B in the palatographic series. Photographic enlargements from a motion picture film showing the lip positions of Subject II when articulating the three phonological degrees of length of vowels are reproduced in the present work.

At this stage the author would like to express his deepest gratitude to his informants A. Eelmäe, V. Hallap, R. Kull, M. Norvik, E. Pajusalu, V. Pall and L. Vellerand for all the trouble and loss of time they incurred in connection with the preparation of this work which could never have been completed but for their valuable and entirely uncompensated help.

Marking phonological quantity. In this study (as is usual in the transcription of Fenno-Ugric languages) a vowel symbol without any additional mark represents a vowel of the first phonological degree of length, the mark ¯ indicates the long or second degree of length and ˆ, the over-long or third degree of length. An allochronic "semi-long" vowel is denoted by means of the mark ˋ. It might be added that the symbol ę corresponds to the letter õ used in spelling.

Note. X-ray photographs of $\bar{o}$ and $\bar{i}$ of the second phonological degree of length yield quite amazing results. The articulation of the first sound is unusually close and even palatal, that of the second, however, is surprisingly open. These articulations vary only slightly in the case of our five subjects. In order to draw any final conclusions, one probably requires an even greater amount of material.

DESCRIPTION OF ESTONIAN VOWELS

The *i*-sounds

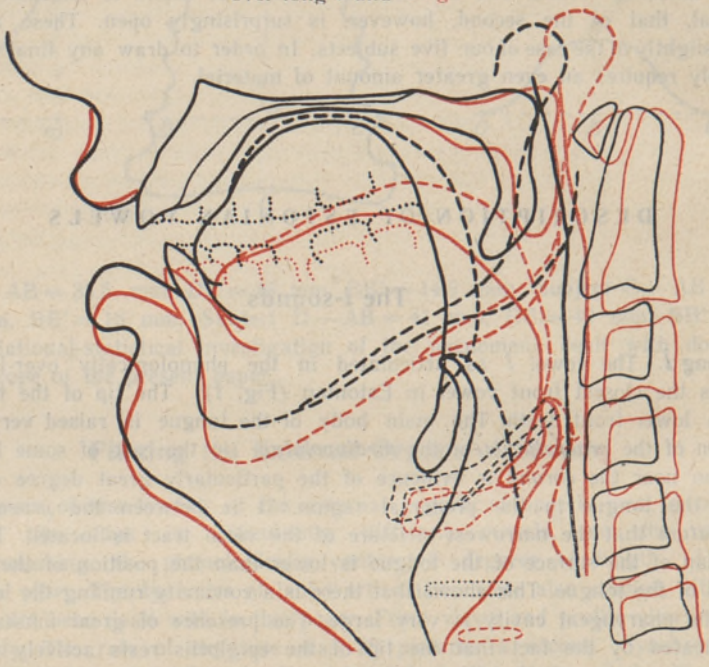
Over-long *î*. The vowel *î* as articulated in the phonologically over-long degree of length is the closest front vowel in Estonian (Fig. 1). The tip of the tongue rests against the lower front teeth. The main body of the tongue is raised very tensely in the direction of the *praepalatum* or the *mediopalatum* (in the case of some informants). A depression near the *corona* is evidence of the particularly great degree of muscular tension of the tongue in the predorsal region. It is between the *praedorsum* and the *praepalatum* that the narrowest stricture of the vocal tract is located. The position of the median of the surface of the tongue is lower than the position of the projections of the sides of the tongue. This shows that there is a concavity running the length of the dorsum. The pharyngeal cavity is very large. The presence of great muscular tension is also indicated by the fact that the tip of the epiglottis rests actively against the root of the tongue and that the *valleculae glossoepiglotticae* are relatively open. The position of the larynx is fairly high. The velum is raised upwards, and, consequently, the *velic* stricture[46] is very narrow. The jaws draw considerably closer together, the opening of the lips is narrow, the lips are spread. The latter phenomenon is particularly noticeable in the case of Subject II (see Fig. 3).

The prepalatal narrowest stricture of the air passage can also be seen from the corresponding palatogram (Fig. 2). This stricture may occasionally be so narrow as to cause a certain amount of fricativity. The palatogram also shows a widening of the air passage in the postpalatal region.

Long *ī*. The articulation of $\bar{i}$ of the second degree of length is quite remarkably lower and more retracted (Fig. 1). The body of the tongue is curved slackly in the direction of the *postpalatum* or even the velum. The pharyngeal cavity is very markedly smaller. The narrowest stricture of the vocal tract is between the root of the tongue and the posterior wall of the pharnyx. In the pronunciation of Subject V, the body of the hyoid bone (*corpus ossis hyoidei*) has been lower and slightly more retracted than when pronouncing *î*, and the greater horns (*cornua majora*) have been directed slightly more downwards. The position of the vocal cords is lower. In the pronunciation of Subjects II, III and IV, however, the position of the larynx when articulating the long $\bar{i}$ has been somewhat higher than in the case of over-long *î*. On the whole, we feel inclined to assume a different laryngeal articulation in the case of long and over-long *i*. It is probably here that one must look for an explanation of why the general acoustic effect is still qualitatively that of *i* despite the unusual openness of the oral articulation. The position of the velum is slightly lower. The distance between the front teeth and the opening of the lips usually increases a little in the vertical direction. In

[46] The *velic* is the upper part of the soft palate facing the *nasopharynx*, and therefore the *velic* stricture (resp. closure) represents the stricture (resp. closure) of the nasal passage.

Fig. 1. Subject V. Röntgenogram of Estonian over-long *î* and long *i*.



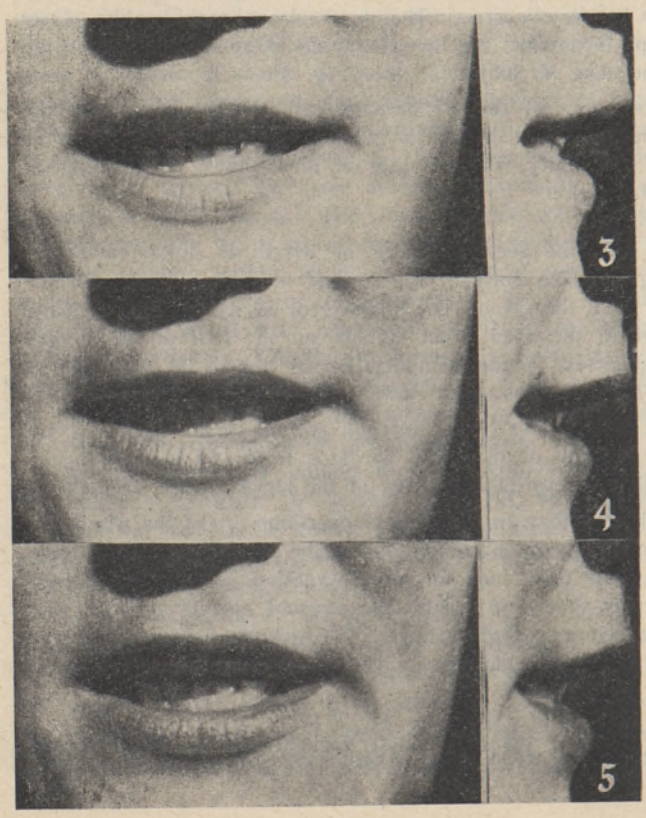
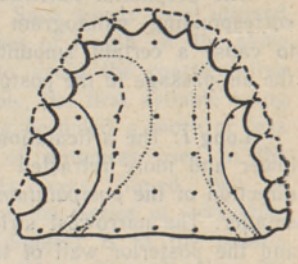


Fig. 2. Subject B. Palatogram * of Estonian over-long *î*, long *ī* and short *i*.



Note. In the palatograms

a dotted line . . . . . denotes an over-long monophthong;

a broken line - - - - - denotes a long monophthong;

a continuous line ——— denotes a short monophthong.

* See the explanation of the asterisk on p. 49.

Fig. 3. Lip-position of Estonian over-long *î*.

Fig. 4. Lip-position of Estonian long *ī*.

Fig. 5. Lip-position of Estonian short *i*.

such a case the muscular tension of the lips grows slightly slacker in a horizontal direction. When $\bar{i}$ is pronounced by Subject II, the angle of the jaws is slightly smaller than when $\hat{i}$ is articulated, and there is also a little more muscular tension of the lips horizontally (see Fig. 4). This can obviously be accounted for by a tendency to compensate for the very open articulation. The palatogram shows a considerable widening of the air passage (Fig. 2).

Short *i*. The contact area of the tongue and the palate revealed by the palatogram (Fig. 2) shows that the articulation of phonologically short *i* is even lower and more velar. Fig. 5 shows that the opening between the jaws increases slightly, the opening of the lips widens and the corners of the mouth draw closer to each other.

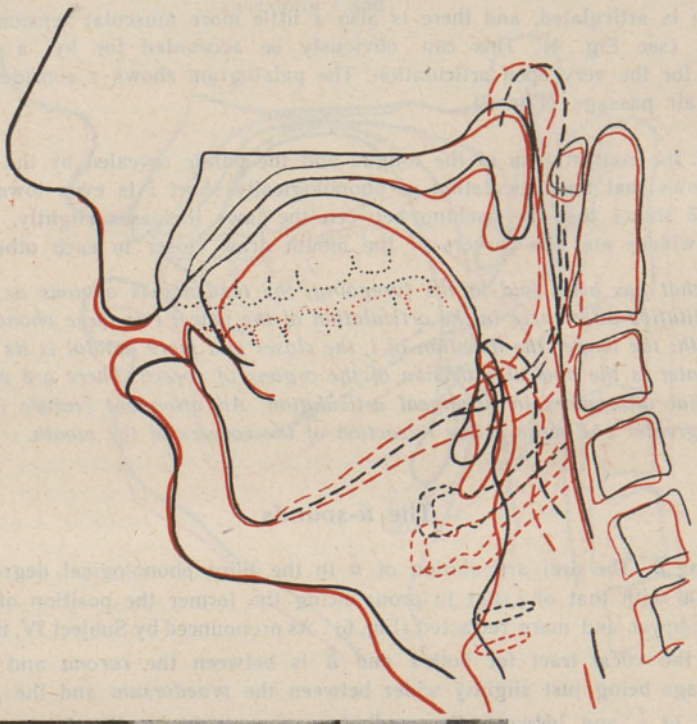
From what has been said in the foregoing, the tendency is obvious as regards the marked qualitative differences in the articulation of the vowel i in three phonological degrees of length: the longer the duration of i, the closer and more palatal is its articulation, and the greater is the muscular tension of the organs of speech. There are probably also some essential differences in laryngeal articulation. An attendant feature is the correspondingly greater and more active retraction of the corners of the mouth.

The *ü*-sounds

Over-long *û*. The oral articulation of $\hat{u}$ in the third phonological degree of length is comparable with that of $\hat{i}$, but in pronouncing the former the position of the tongue is somewhat lower and more retracted (Fig. 6). As pronounced by Subject IV, the narrowest stricture of the vocal tract for both $\hat{i}$ and $\hat{u}$ is between the *corona* and the *alveoli*, the air passage being just slightly wider between the *praedorsum* and the *praepalatum* in the case of $\hat{i}$, and between the *mediodorsum* and the *mediopalatum* in the case of $\hat{u}$. The width of the pharyngeal cavity in a horizontal direction is approximately the same, but the size of the pharynx is notably greater in a vertical direction: the position of the hyoid bone is appreciably lower and more advanced, the greater horns are directed slightly more upwards, the position of the vocal cords is markedly lower. The velum is a shade less raised. The distance between the front teeth is smaller. There is active horizontal as well as vertical labialization attended by a protrusion of the lips (Fig. 8). The degree of labialization, however, is slightly smaller than in the case of $\hat{u}$ (cf. Figs. 8 and 54; for the latter, see No. 2 of the present publication for 1961). The reduction of linguopalatal articulation may be graphically seen from a comparison of the pertinent palatograms (cf. Figs. 7 and 2).

Long *ū*. A comparison of the articulation of $\bar{u}$ and $\bar{i}$ in the second degree of phonological length (Fig. 11) shows a most striking difference in oral articulation and in the volume of the pharynx: the articulation of $\bar{u}$ is much closer and more palatal. The main body of the tongue curves actively towards the *mediopalatum*. The greatest muscular tension seems to be in the region of the *mediodorsum*. The tip of the tongue rests against the lower *alveoli* in both $\bar{u}$ and $\bar{i}$, but its position is notably higher for $\bar{u}$. The narrowest degree of stricture is between the *mediodorsum* and the *mediopalatum* in $\bar{u}$, but between the root of the tongue and the back wall of the pharynx in the case of $\bar{i}$. The pharynx is very notably wider. The tongue-position is more like that for over-long $\hat{i}$. Since the difference in tongue-position so clearly distinguishes the resonance quality of the oral and pharyngeal cavities, the position of the larynx differs but slightly (the hyoid bone being only somewhat more advanced). The velum is a little more raised. The angle between the jaws is a shade smaller than in the case of $\bar{i}$. Subject V has pronounced $\bar{u}$ with quite open labialization.

Fig. 6. Subject IV. Röntgenogram of Estonian over-long *î* and over-long *û̂*.



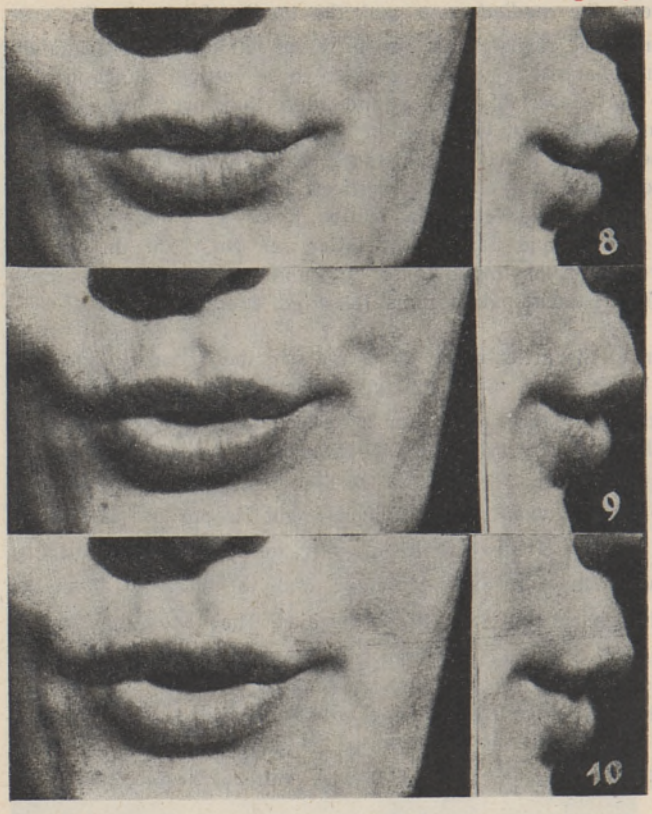


Fig. 8. Lip-position of Estonian over-long *ú*.

Fig. 9. Lip-position of Estonian long *ü*.

Fig. 10. Lip-position of Estonian short *ü*.

Fig. 11. Subject V. Röntgenogram of Estonian long $\bar{\imath}$ and long $\bar{u}$.

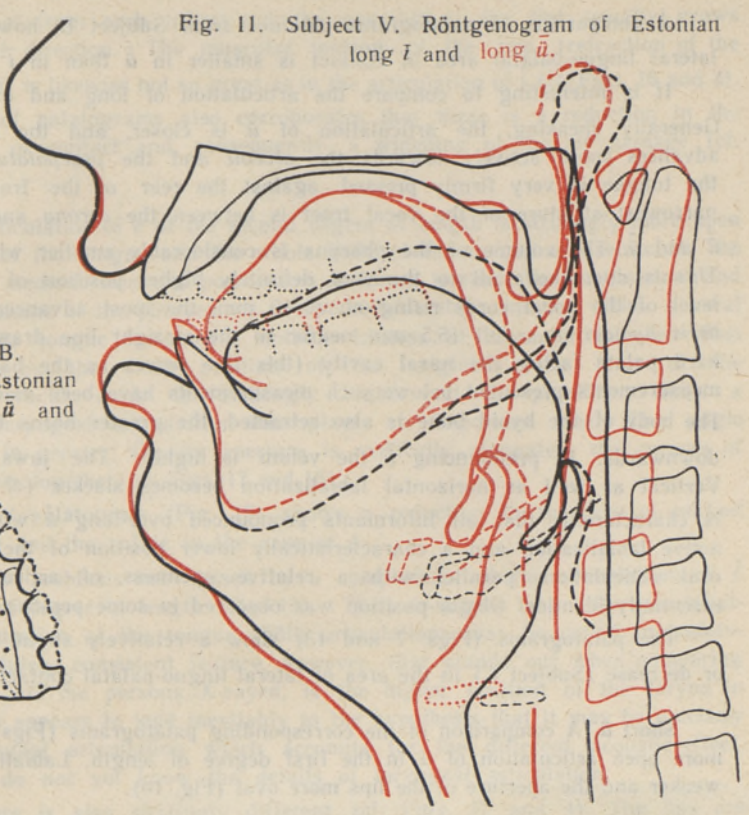


Fig. 7. Subject B. Palatogram * of Estonian over-long $\hat{u}$, long $\bar{u}$ and short $\breve{u}$.

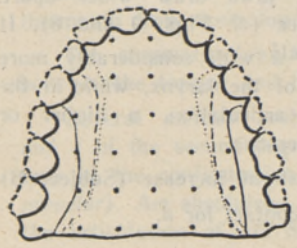


Fig. 12. Subject IV. Röntgenogram of Estonian over-long $\hat{u}$ and long $\bar{u}$.

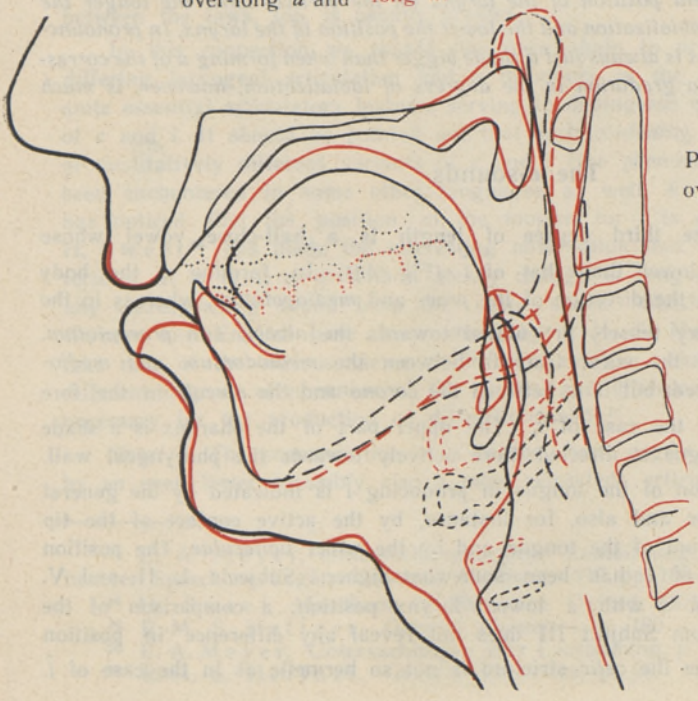
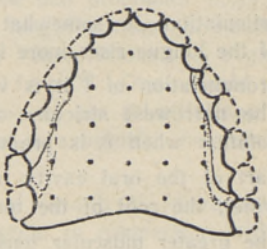


Fig. 13. Subject C. Palatogram * of Estonian over-long $\hat{u}$, long $\bar{u}$ and short $\breve{u}$.



A comparison of palatograms obtained from Subject B, however, shows that the lateral linguo-palatal area of contact is smaller in $\bar{u}$ than in $\bar{i}$ (cf. Figs. 7 and 2).

It is interesting to compare the articulation of long and over-long *ü* (Fig. 12). Generally speaking, the articulation of $\bar{u}$ is closer, and the body of the tongue advances more actively towards the *alveoli* and the *praepalatum*. Even the tip of the tongue is very firmly pressed against the rear of the front lower teeth. The narrowest stricture of the vocal tract is between the *corona* and the *alveoli* in both $\bar{u}$ and $\hat{u}$. The volume of the pharynx is considerably smaller when $\bar{u}$ is pronounced. This is due, above all to the very definitely higher position of the larynx: with the level of the vocal cords rising about 10 mm, the most advanced part of the *corpus ossis hyoidei* is a full 15.5 mm nearer to the straight line drawn along the side of hard palate facing the nasal cavity (this line serves as the basis for other similar measurements presented below; such measurements have been made at a right angle). The body of the hyoid bone is also retracted, the greater horns turning slightly more downwards. In pronouncing $\bar{u}$ the velum is higher. The jaws draw wider apart. Vertical as well as horizontal labialization becomes slacker (cf. Figs. 9 and 8). It is characteristic that all informants pronounced over-long $\hat{u}$ with considerably more active labialization and a characteristically lower position of the larynx, while in the oral articulation, parallel with a relative openness of articulation, a higher or essentially identical tongue-position was observed in some persons.

The palatograms (Figs. 7 and 13) show a relatively slight increase (Subject B) or decrease (Subject C) in the area of lateral linguo-palatal contact for $\hat{u}$.

Short *ü*. A comparison of the corresponding palatograms (Figs. 7 and 13) reveals a more open articulation of *ü* in the first degree of length. Labialization is appreciably weaker and the aperture of the lips more oval (Fig. 10).

The distinctive articulatory features of the ü-sounds of the over-long, long and short degrees of length with their distinct tamber, are the different degree of labialization and the different position of the larynx on the vertical axis: the longer the vowel, the more active the labialization and the lower the position of the larynx. In pronouncing ü the aperture of the lips is always just a shade bigger than when forming u of the corresponding degree of length; a gradation in the degrees of labialization, however, is much more evident.

The *e*-sounds

Over-long *ê*. *ê* of the third degree of length is a half-close vowel whose articulation is somewhat lower than that of $\hat{i}$ (Fig. 14). In forming *ê* the body of the tongue rises more in the direction of the *prae-* and *mediopalatum*, whereas in the pronunciation of $\hat{i}$ it is very tensely articulated towards the *alveoli* and *praepalatum*. The narrowest stricture of the vocal tract is between the *mediodorsum* and *mediopalatum* when *ê* is produced, but it is between the *corona* and the *alveoli* in the fore part of the oral cavity in the case of $\hat{i}$. The upper part of the pharynx is a shade wider, the root of the tongue is directed more actively towards the pharyngeal wall. The greater muscular tension of the tongue in producing $\hat{i}$ is indicated by the general configuration of the tongue and also, for instance, by the active contact of the tip of the epiglottis with the root of the tongue and by the wider *valleculae*. The position of the larynx in the case of *ê* has been somewhat higher. Subjects I, II and V, however, have pronounced *ê* with a lower larynx position; a comparison of the röntgenograms obtained from Subject III does not reveal any difference in position of larynx. At the same time the *velic* stricture is not so hermetic as in the case of $\hat{i}$.

The jaws draw apart from each other and the opening of the lips usually grows wider in a vertical direction. The muscular tension of the lips (retraction of the corners of the mouth) is likewise not so great as in the articulation of $\bar{i}$ (cf. Figs. 16 and 3).

A comparison of palatograms also corroborates that there is a reduction in the linguo-palatal area of contact and, consequently, a widening of the air passage (cf. Figs. 15 and 2).

Long *ē*. The articulation of $\bar{e}$ of the second degree of length is strikingly more open (Fig. 20). The tip of the tongue and the whole body of the tongue are retracted. The region between the *mediodorsum* and *postdorsum* is raised towards the *postpalatum* and *praevelum*. The volume of the pharynx is very considerably smaller. The general configuration of the tongue indicates a notable laxness of muscular tension. This is also indicated by the slack position of the epiglottis. The level of the hyoid bone and vocal cords is strikingly higher. It is possible that a difference in the laryngeal articulation also plays an important role. The angle between the jaws is greater, the lip aperture is vertically elongated, the corners of the mouth draw closer together (cf. Figs. 17 and 16).

The summarized palatogram (Fig. 15) shows a reduction in the area of contact between the tongue and the palate in the case of $\bar{e}$.

Several serious problems are raised by a comparison of the articulations of $\bar{i}$ and $\bar{e}$ of the second degree of length (Fig. 19). There is hardly any difference whatever in the configuration of the tongue (both articulations may be called *postpalato-prevelar*). An absolutely consistent feature, however, that stands out when comparing the articulation of all the persons X-rayed, is the higher position of the larynx in pronouncing $\bar{e}$. This appears to lead inevitably to the hypothesis that it may be precisely the different laryngeal articulation which accounts for the different acoustic effect. Unfortunately we do not yet know the details of laryngeal articulation.

The lip aperture is also strikingly different (cf. Figs. 17 and 4). The lips are drawn notably apart from each other. The active muscular tension in a horizontal direction that occurs in the articulation of $\bar{i}$ is absent in the case of $\bar{e}$. The angle between the jaws, too, is usually greater.

In this connection we should like once again to propound the hypothesis that differing laryngeal articulation and a difference in the opening of the lips may be quite essential articulatory features serving to distinguish qualitatively different variants of *e* and *i*. It should be pointed out that such confusing facts in the oral articulation of qualitatively different variants of *e* and *i* (the phenomenon of "overlapping") have been encountered in some other languages as well. E. A. Meyer[47], for instance, has noticed that the position of the tongue for *ɪ* is often lower than that for *e*. H. Sweet[48] has made the interesting observation that one can pronounce either the series *i*, *e*, *æ* or *ɪ*, *ɛ*, *ɐ* with a steady change in tongue height without articulating any corresponding sound from the other series. Similar observations as regards German and English have been made by R.-M. S. Heffner.[49] One should also take note of the various views on different relative volumes of air ("Luftfüllung")[50], different degrees of openness of the glottis, and differences in subglottal air pressure necessary for the production of different vowels.[51]

Short *e*. The pronunciation of *e* of the first degree of length is characterized by an even lower (possibly also a more retracted) articulation in comparison with $\bar{e}$.

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[47] E. A. Meyer, Untersuchungen über Lautbildung. Festschrift für Viëtor. «Die neueren Sprachen», Ergänzungsband. Marburg, 1910, pp. 168—248.

[48] H. Sweet, Handbook of Phonetics. Oxford, 1877, pp. 8—10.

[49] R.-M. S. Heffner, General Phonetics, p. 100.

[50] E. A. Meyer, Untersuchungen über Lautbildung, p. 237.

[51] R.-M. S. Heffner, General Phonetics, p. 96.

Fig. 14. Subject IV. Röntgenogram of Estonian over-long *î* and over-long *ê*.

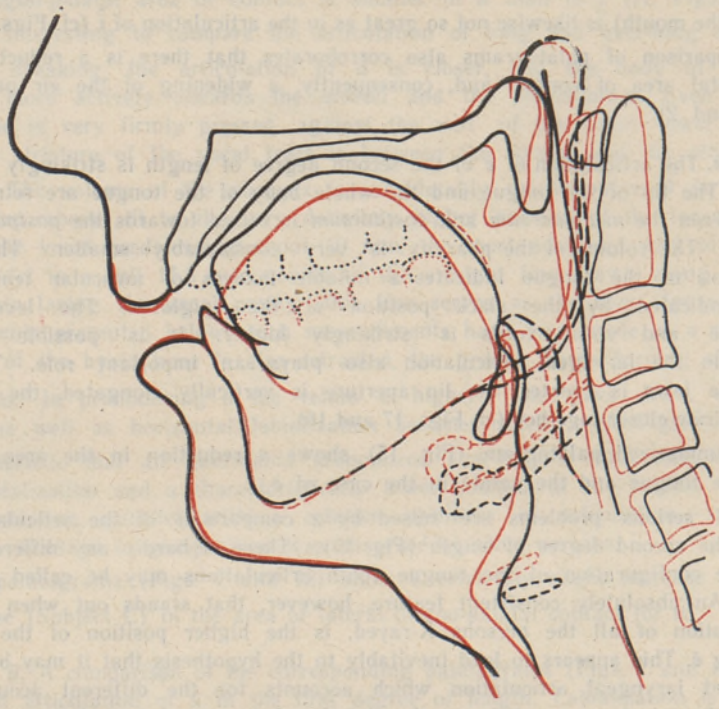


Fig. 15. Subject B.

Palatogram of Estonian over-long *ê*, long *ē* and short *e*.

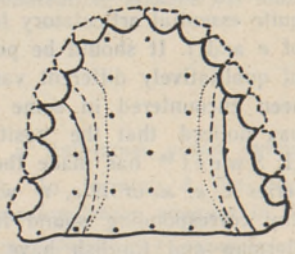


Fig. 16. Lip-position of Estonian over-long *ê*.

Fig. 17. Lip-position of Estonian long *ē*.

Fig. 18. Lip-position of Estonian short *e*.

Fig. 19. Subject IV. Röntgenogram of Estonian long *ī* and long *ē*.

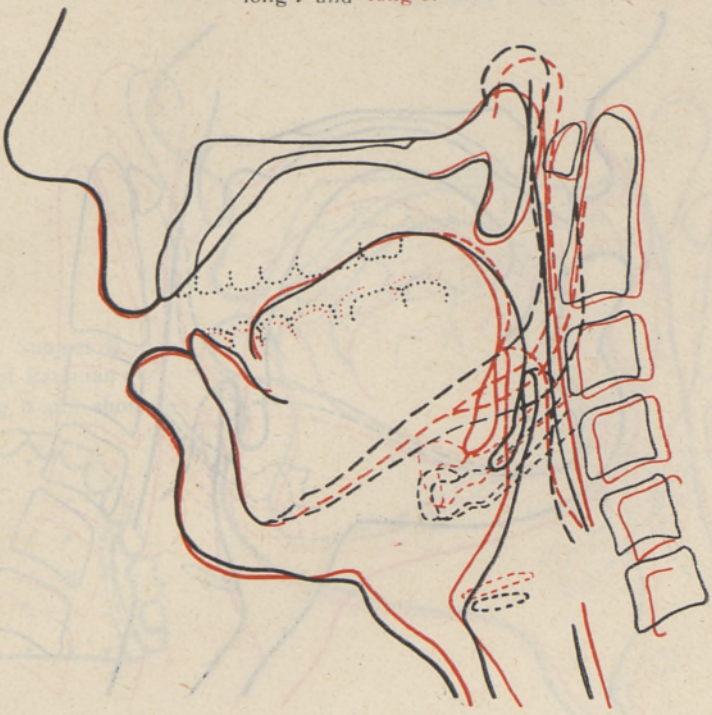


Fig. 20. Subject II. Röntgenogram of Estonian over-long *ê* and long *ē*.

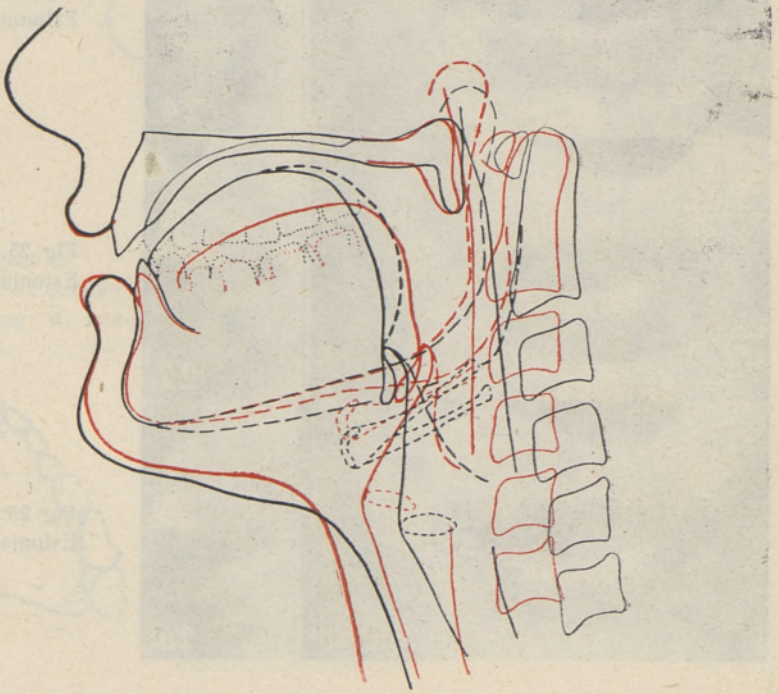


Fig. 21. Subject I. Röntgenogram of Estonian over-long *ê* and over-long *ô*.

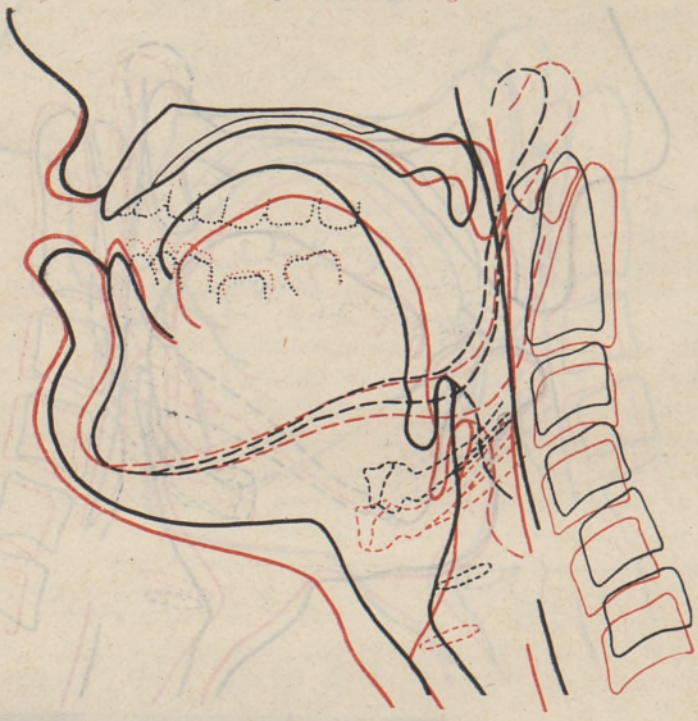


Fig. 24. Lip-position of Estonian over-long *ô*.

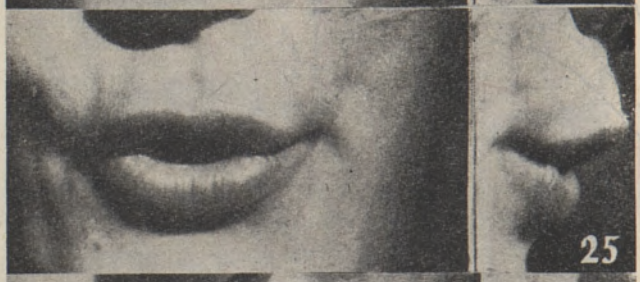


Fig. 25. Lip-position of Estonian long *ō*.

Fig. 26. Lip-position of Estonian short *ŏ*.

Fig. 27. Subject I. Röntgenogram of Estonian over-long $\hat{u}$ and over-long $\hat{o}$.

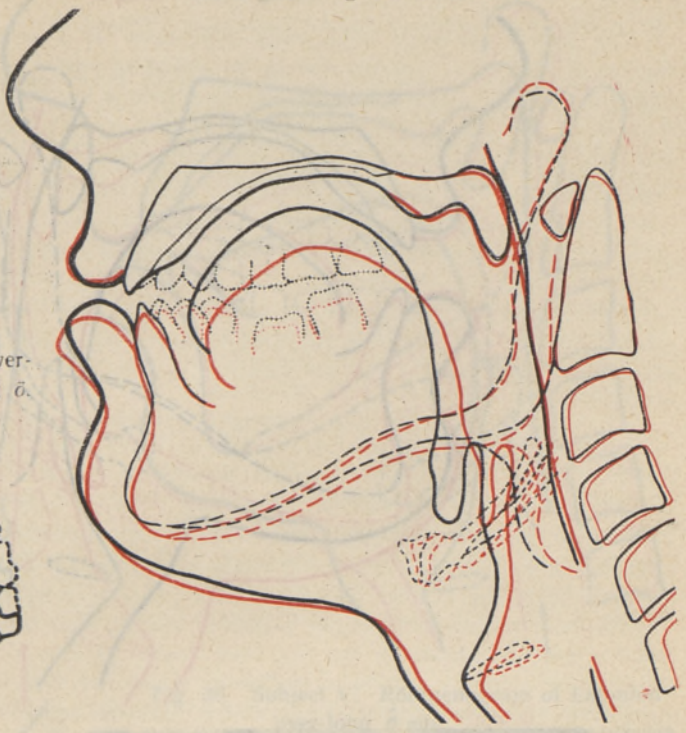


Fig. 22. Subject B. Palatogram of Estonian over-long $\hat{o}$, long $\bar{o}$ and short $\breve{o}$.

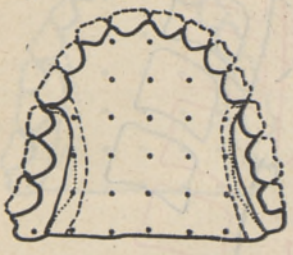


Fig. 28. Subject I. Röntgenogram of Estonian long $\bar{u}$ and long $\bar{o}$.

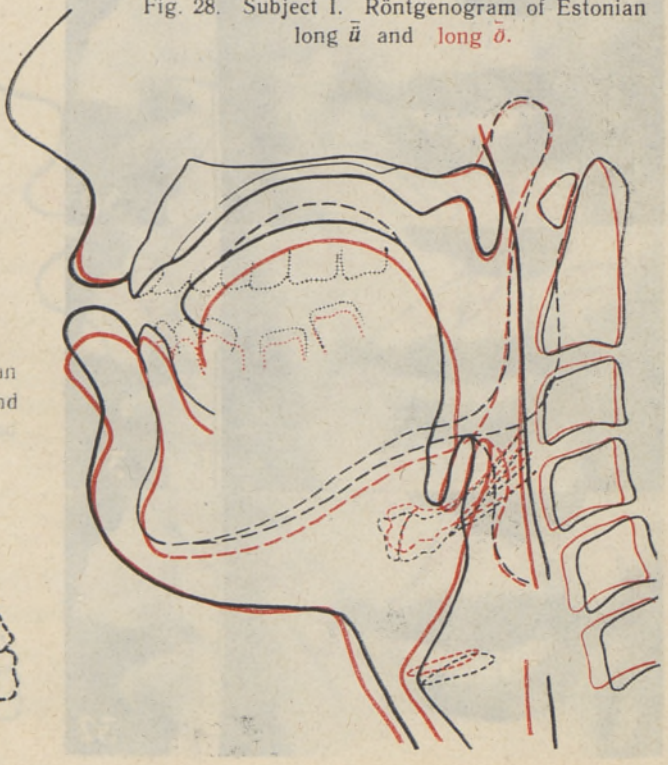


Fig. 23. Subject D. Palatogram * of Estonian over-long $\hat{o}$, long $\bar{o}$ and short $\breve{o}$.

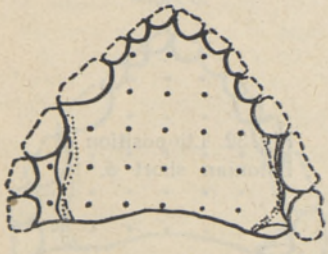
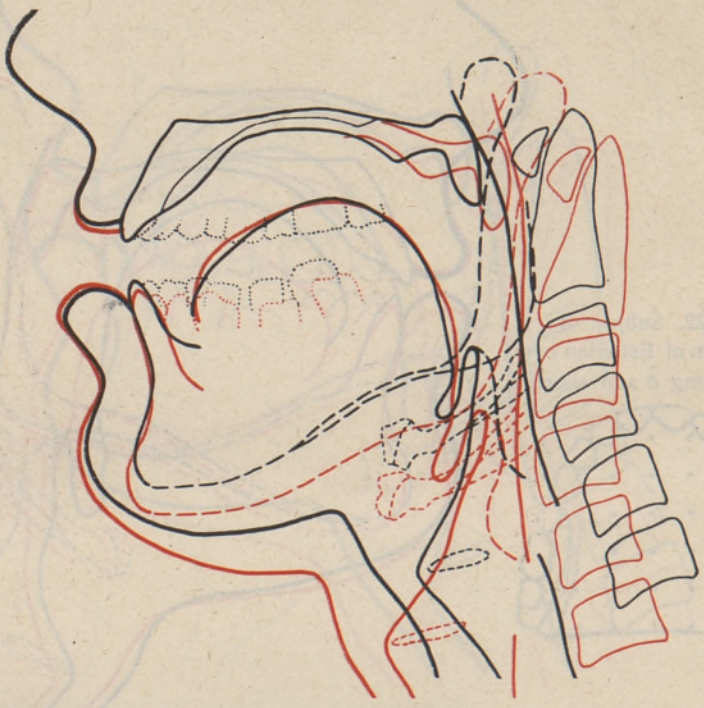


Fig. 29. Subject I. Röntgenogram of Estonian long $\bar{e}$ and long $\bar{o}$.



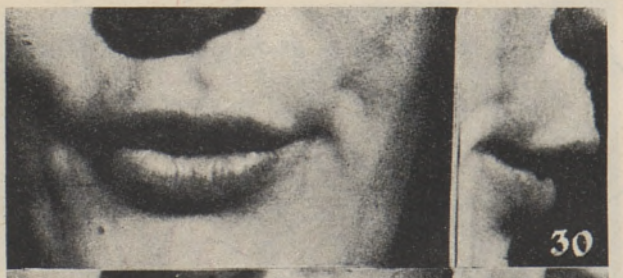


Fig. 30. Lip-position of Estonian over-long $\hat{\bar{o}}$.

Fig. 31. Lip-position of Estonian long $\bar{\ddot{o}}$.

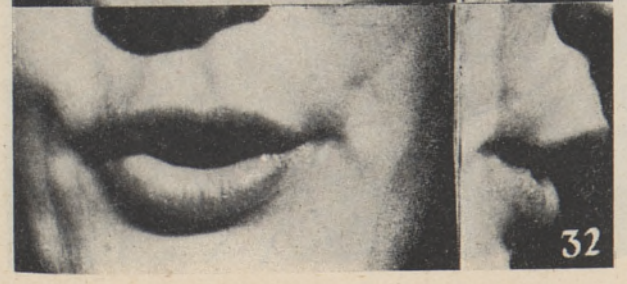


Fig. 32. Lip-position of Estonian short $\ddot{o}$.

Fig. 35. Subject IV. Röntgenogram of Estonian over-long $\hat{o}$ and long $\bar{o}$.

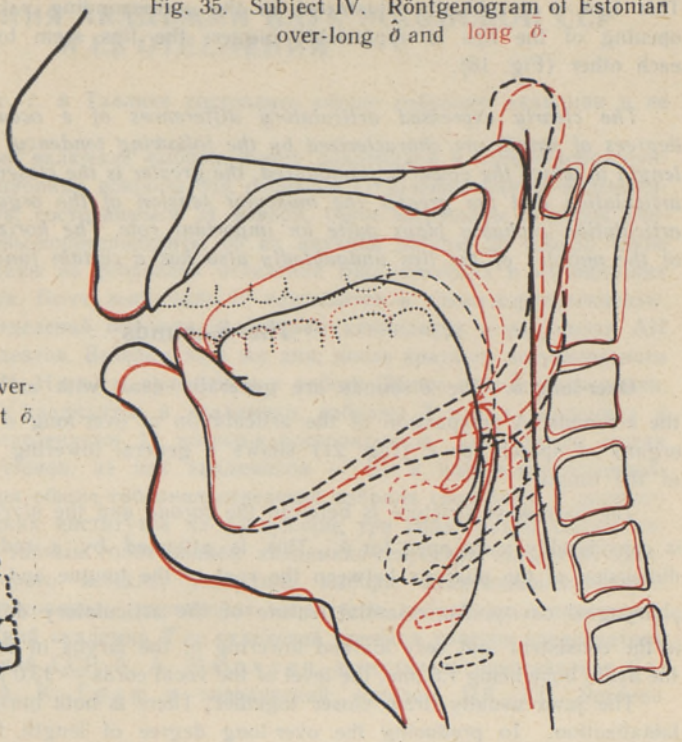


Fig. 33. Subject B.

Palatogram of Estonian over-long $\hat{o}$, long $\bar{o}$ and short $\breve{o}$.

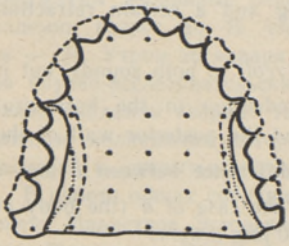


Fig. 36. Subject V. Röntgenogram of Estonian over-long $\hat{o}$ and long $\bar{o}$.

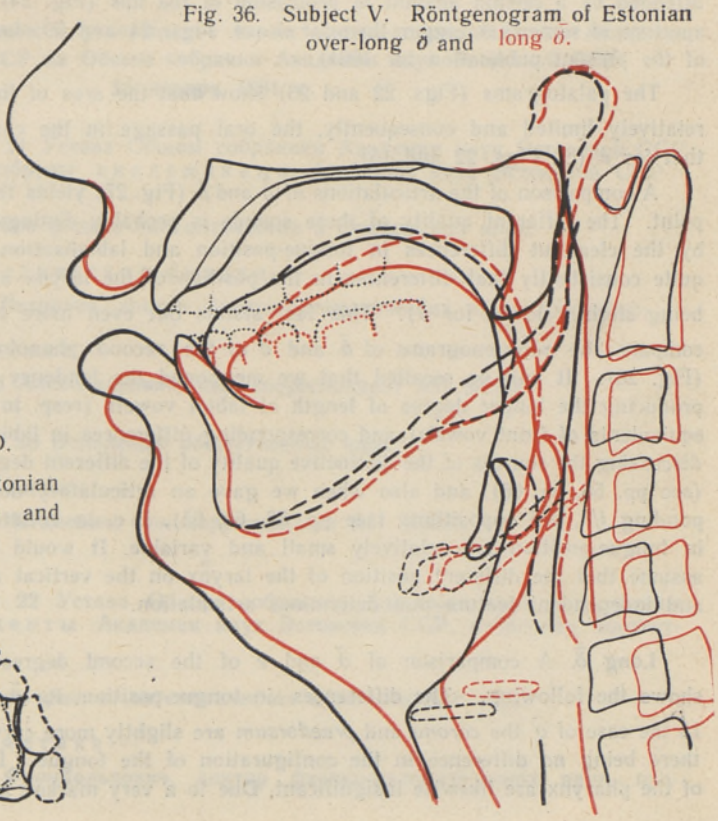
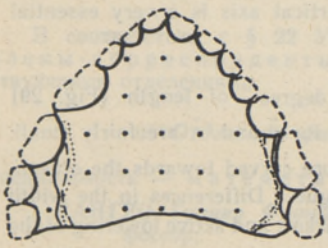


Fig. 34. Subject D.

Palatogram * of Estonian over-long $\hat{o}$, long $\bar{o}$ and short $\breve{o}$.



This fact is graphically illustrated in the corresponding palatograms (Fig. 15). The opening of the lips is appreciably bigger: the lips seem to be pushed away from each other (Fig. 18).

The clearly expressed articulatory differences of e occurring in three different degrees of length are characterized by the following tendency: the longer the degree of length in which the vowel is pronounced, the greater is the closeness and palatal nature of articulation and the greater the muscular tension of the organs of speech. Laryngeal articulation probably plays quite an important role. The horizontal tension or laxness of the muscles of the lips undoubtedly also has a certain function.

The ö-sounds

Over-long ö̂. The ö-sounds are generally dealt with as labialized equivalents of the *e*-sounds. A comparison of the articulation of over-long ö̂ with the position of the organs of speech for ê (Fig. 21) shows a general lowering and a certain retraction of the tongue.

The narrowest stricture is between the *corona* and the *alveoli* in both sounds, but it is considerably more open for ô̂. This is attended by a reduction in the horizontal dimension of the pharynx between the root of the tongue and the posterior wall of the pharyngeal cavity. An essential feature of the articulatory difference between ö̂ and ê is the consistent and very marked lowering of the larynx in the case of ö̂ (the body of the hyoid bone being 7.5 mm, the level of the vocal cords — 13.0 mm lower).

The jaws usually draw closer together. There is both horizontal as well as vertical labialization. In producing the over-long degree of length, labialization is active and attended by a certain amount of protrusion of the lips (Fig. 24). Nevertheless, the lip aperture is somewhat bigger then for ô̂ (cf. Figs. 24 and 59; for the latter, see No. 2 of the present publication for 1961).

The palatograms (Figs. 22 and 23) show that the area of linguo-palatal contact is relatively limited and consequently, the oral passage in the case of ö̂ is wider than that for ê (cf. Figs. 22 and 15).

A comparison of the articulations of ô̂ and û̂ (Fig. 27) yields the following interesting point. The different quality of these sounds is probably distinguished quite sufficiently by the clear-cut differences in tongue-position and labialization. Therefore one finds quite consistently that differences in the position of the larynx are minimal (the larynx being slightly lower for û̂). This fact stands out even more conspicuously when we compare the röntgenograms of ū̄ and ō̄ of the second phonological degree of length (Fig. 28). It will be recalled that we mentioned the tendency to lower the larynx in producing the longer degree of length of labial vowels (resp. in forming the labialized equivalents of front vowels) and corresponding differences in labialization when we were discussing the sources of the distinctive quality of the different degrees of length of ü or ö (see pp. 56, 65, 66), and also when we gave an articulatory description of the corresponding *i/ü, e/ö* oppositions (see pp. 53, 64, 65), i. e. in such cases where differences in tongue-position are relatively small and variable. It would thus appear logical to assume that the different position of the larynx on the vertical axis is a very essential and independent feature that determines articulation.

Long ȫ. A comparison of ō̄ and ē of the second degree of length (Fig. 29) shows the following. The differences in tongue-position for ō̄ and ē are fairly small. In the case of ō̄ the *corona* and *praedorsum* are slightly more curved towards the *alveoli*, there being no difference in the configuration of the tongue. Differences in the width of the pharynx are likewise insignificant. Due to a very marked and active lowering of the

larynx, however, there is a very striking increase in the vertical extent of the pharynx (the body of the hyoid bone is 12 mm, the level of the vocal cords even 17 mm lower). It is probable that this is one of the most characteristic features of the articulation of long $\bar{o}$. The narrowest stricture within the vocal tract is between the *corona* and the *alveoli* for $\bar{o}$, but between the medio-postdorsal region and the *praevelum* in the case of $\bar{e}$.

The angle between the jaws varies for different persons. Labialization is half-open (see röntgenogram in Fig. 29). Approximately half-close labialization is shown in Fig. 31.*

As may be seen from Figs. 33 and 15, there is less linguo-palatal contact for $\bar{o}$ than for $\bar{e}$. The extent of the contact area varies in the case of different persons (cf. Figs. 33 and 34).

Which are the articulatory differences between long and over-long *ö*? A comparison (Fig. 35) of the corresponding röntgenograms obtained from Subject IV shows that when both $\bar{o}$ and $\hat{o}$ are formed, the tongue rests against the lower *alveoli*, but the tip, *corona* as well as the whole body of the tongue are somewhat higher for $\bar{o}$ than for $\hat{o}$. In the case of $\bar{o}$ the upper two thirds of the pharynx are narrower, while the lower third is wider. The volume of the pharyngeal resonance chamber is reduced still further by the actively higher position of the larynx (the body of the hyoid bone is 13 mm, the level of the vocal cords — 10 mm higher). The narrowest stricture in the vocal tract is between the root of the tongue and the posterior pharyngeal wall for $\hat{o}$, but between the medio-postdorsal region and the *praevelum* when pronouncing $\bar{o}$. In the latter case the velum is not so tensely raised. The jaws are slightly drawn apart. The difference in lip-position is also important. In forming $\hat{o}$ the lips are drawn closer to each other (the lip aperture for $\bar{o}$ is 14 mm in vertical projection, and 6.9 mm for $\hat{o}$) and their protrusion has also been observed. There is thus less labialization in the case of long $\bar{o}$.

It is of interest both from the viewpoint of articulatory variability and that of compensatory articulation to compare the aforegoing with data obtained from Subject V. An important difference is the generally lower configuration of the tongue for $\bar{o}$ (Fig. 36). The narrowest stricture within the vocal tract is between the *corona* and the *alveoli* for $\hat{o}$, and between the root of the tongue and the posterior wall of the pharynx for $\bar{\bar{o}}$. The body of the hyoid bone is on approximately the same level, the position of the vocal cords about 5 mm lower for $\hat{o}$. At the same time, however, there is very active labialization in the case of over-long $\hat{o}$ (measured vertically, the lip aperture is 22.5 mm for $\bar{o}$, but 9.2 mm for $\hat{o}$) attended by marked protrusion of the lips.

It may be assumed that the very high degree of labialization and closer articulation, characteristic of the pronunciation of over-long $\hat{o}$ by Subject V, produce the same acoustic effect as the lower tongue-position, weaker labialization and considerable lowering of the larynx that occur in the case of Subject IV.

The relatively higher or lower tongue-positions for long $\bar{o}$ can also be seen from the corresponding reduction or increase of linguo-palatal contact in the palatograms (Figs. 33, 34). Differences in the degree of labialization are shown in Figs. 30 and 31.

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* In order to give the reader a complete picture of the corresponding vowels, we have presented in the last complex of illustrations the lip-positions and palatograms of different degrees of *ö* for a second time; in the numeration of illustrations Fig. 30 corresponds to Fig. 24; Fig. 31 — to Fig. 25, Fig. 32 — to Fig. 26, Fig. 33 — to Fig. 22, and Fig. 34 — to Fig. 23.

Short *ö*. The pronunciation of short *ö* is characterized by greater openness of articulation, the latter being more open both in relation to *ö* of the second and third phonological degrees of length (Figs. 33, 34) and to short *e* (cf. Figs. 33 and 15), as well as by half-open labialization (Fig. 32).

In our opinion the distinctive articulatory features underlying the qualitative differences of ö in the three phonological degrees of length include the different degrees of labialization and the different positions of the larynx on the vertical axis: the longer the degree of length, the closer the labialization and the lower the position of the larynx. The lip aperture always remains slightly more open than for the corresponding degree of length of o.

(To be continued)