CONSONANT QUANTITY AND PHONOLOGICAL UNITS IN ESTONIAN

by Ilse Lehiste

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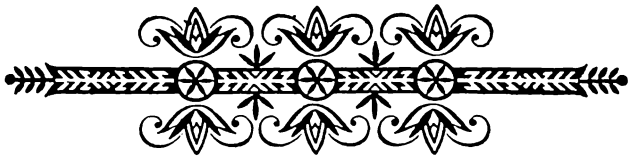


1. Introduction

This paper explores the function of quantity in establishing the structure of phonological units in Estonian. In particular, the duration of plosive consonants and sibilants is examined in order to discover to what extent their duration serves as a signal for segmenting the stream of speech into phonological units.[1]

A brief summary of the function of the suprasegmental feature of quantity in Estonian appears necessary before the specific problem discussed in this paper may be introduced.[2] Quantity functions in Estonian both on the segmental and on the syllabic level; it also plays a part in the formation of higher-level phonological units.[3] The manifestation of quantity at the different levels appears to follow rather complicated rules.

The phoneme inventory of Estonian consists of nine vowel phonemes, /i, e, ä, a, o, u, ü, ö, õ/, and 14 consonant phonemes, /p, t, t', k, m, n, n', v, s, s', l, l', r, h/. All phonemes except /v/ may occur in three phonemically distinct quantities, which will be referred to by the numbers 1, 2, and 3 in this paper. On the segmental level, the term quantity 1 applies to the short quantity of vowels and consonants; quantity 2 refers to the quantity associated with long vowels and diphthongs and with long consonants, often called short geminates; and quantity 3 designates the quantity of overlong vowels and diphthongs and of overlong consonants.[4]

The position in which a maximum number of contrasts is manifested is the first syllable of polysyllabic words, in which all vowels may occur in three contrastive quantities, and 19 of the 23 diphthongs may occur in two contrastive quantities. All consonants except /v/ occur likewise in three contrastive quantities in intervocalic position between the first and the second syllable of polysyllabic words. In monosyllabic words, vowels

may occur either in quantity 1 or quantity 3. Vowel quantity, however, is in a complementary relationship with consonant quantity, so that only the following vowel + consonant combinations occur in monosyllabic words: vowel in quantity 1 + consonant in quantity 3; vowel in quantity 3 + consonant in quantity 1; and vowel in quantity 3 + consonant in quantity 3.[5] Vowel quantity is not independently variable in any other position. Contrasts between consonants in different quantities may occur in certain other positions, which will be described below in some detail.

In word-initial position consonant quantity is noncontrastive. This fact is potentially significant as a means of signalling word boundaries. Phonetically, the duration of word-initial consonants is intermediate between those of consonants in segmental quantities 1 and 2. The presence of a consonant in this intermediate quantity may serve as a signal of the presence of a word boundary. The process by which compound words are gradually adapted to the patterns characterizing noncompound words involves, among other things, the replacement of the noncontrastive quantity of the initial consonant of the second member of the compound by one of the three segmental quantities.

Word-level phonological units may combine into higher-level units of the phonological hierarchy, which may be referred to as phonological phrases. When two or more words are fused into a phonological phrase, it may be assumed that some changes will take place in the phonetic manifestation of the word boundaries.

The present paper constitutes a report of an investigation of the function of the durations of plosive consonants and sibilants in signalling word boundaries on the one hand, and in manifesting the fusion of words into phonological phrases on the other hand.

2. Materials and Methods

The method employed in the investigation consists of spectrographic analysis of 500 utterances, spoken by one informant (the author). A statement appears advisable concerning the use of only one informant. In several other investigations, the author has followed the procedure of basing an acoustic description on the production of selected speech samples by a small number of main informants, who produce a relatively great number of utterances. The results are then checked by the acoustic analysis of a smaller number of utterances by a larger number of informants. In the present case, the description is based on the speech usage of one informant for the practical reason that other informants were not available at the time this research was performed

whose pronunciation, in the considered opinion of the author, would have been unaffected by several years of absence from an Estonian-speaking environment. For this reason the results are presented as tentative, with the provision that they need to be confirmed by further checking when other speakers become available. Nevertheless, the materials are sufficiently extensive to make it possible to establish first level approximations and to set up theories which then may serve as the basis of further research.

The 500 sentences were constructed in order to make it possible to study several aspects of Estonian phonology, only one of which is discussed in the present report. The spectrographically processed material thus constitutes a potential source of further data, which may be used in the description of other aspects of Estonian phonology. A list of the 500 sentences is given in the Appendix.

The sentences were recorded by the author in a soundproof recording room at the Communication Sciences Laboratory of the University of Michigan. The tapes were processed by means of the Bell Telephone Laboratories' Model D Spectrograph available at the Communication Sciences Laboratory of the University of Michigan, and by a Kay Sonagraph available at the linguistic research laboratory of Ohio State University. Broad-band spectrograms were made of every utterance. The measurement techniques used in the processing of acoustic information of this type are well known and will not be repeated here in detail.[6] One fact might nevertheless be recalled. In the acoustic analysis of speech signals, the response time of the filter employed in the analysis is in an inverse relationship to its bandwidth. Thus with a broad-band filter with a bandwidth of 300 cycles per second an instantaneous pulse will be registered on a spectrogram as having an approximate duration of 0.003 seconds. This means that the individual vocal fold flaps of speakers with low and medium-pitched voices (with fundamental frequencies below 300 cps) are clearly displayed on broad-band spectrograms, and that it is possible to determine the duration of voiced sounds with an accuracy of one vocal fold pulse. Similar precision is possible in measuring the duration of voiceless sounds, especially plosives. In measuring the durations of individual segments, an accuracy of $\pm$ 0.005 seconds has been attempted; although the averages are presented with a precision of one millisecond, this does not represent claimed accuracy in direct measurement.

In the report to follow, the durations of various positional allophones of /p t t' k s s'/ are described with reference to Table I and Figures 1 to 7. The values for /t/ and /t'/ as well

as /s/ and /s'/ are combined in Table I. The table gives first the average durations of occurrences of allophones of these phonemes in intervocalic position between the first and second syllable. Initial occurrences are then described in the following order: utterance-initial allophones; word-initial allophones following a word ending in a vowel; word-initial allophones following a word ending in a consonant; and syllable-initial allophones, i. e. occurrences of the consonants as second member of a cluster of two in intervocalic position.[7] The third group of values represents final occurrences: utterance-final allophones; word-final allophones followed by a word beginning with a vowel; word-final allophones followed by a word beginning with a consonant; and syllable-final allophones, i. e. occurrences of the consonants as first member of a cluster of two in intervocalic position. The only intervocalic occurrences given in the table are those found between the first and second syllable of polysyllabic words; occurrences in other positions are, however, discussed in the text.

The same order of presentation is followed in the text. The paper concludes with a summary chapter, in which an attempt is made to interpret the data presented in the report. The 500 sentences are given in the Appendix. Spectrograms of 35 of the 500 utterances are reproduced on seven figures, each of which contains five broad-band spectrograms. Conventional spelling is used in the identification of the utterances and elsewhere in the text.

3. Allophones of /p/

3.1. Intervocalic /p/

In the position between the first and the second syllable, /p/ occurred in the text in all three quantities. The average durations of occurrences of these allophones of /p/, as well as of other positional allophones of /p/ and the other consonants considered in the present paper, are given in Table I. The table contains a rather simplified presentation of the quantity information, and more detail is given in the description offered in the text. Examples of occurrences of most positional allophones of the sounds under study are shown on Figures 1-7 at the end of the paper.

3.1.1. Intervocalic /p/ in quantity 1

The set of 500 sentences contained 16 occurrences of /p/ in quantity 1 in the position between the first and second syllable. The average duration of occurrences of this allophone was 5. 1 centiseconds; the durations ranged from 4 to 7 csec, with a

Average durations, in centiseconds, of various positional allophones of /p t t' k s s'/ in a set of 500 utterances produced by speaker I. L. N=number of occurrences; D=duration in centiseconds.

TABLE I

Allophone	/p/		/t/ and /t'/		/k/		/s/ and /s'/	
	N	D	N	D	N	D	N	D
Intervocalic								
Quantity 1	16	5.1	50	3.0	55	3.6	53	8.9
Quantity 2	6	10.3	20	8.3	10	7.4	2	13.0
Quantity 3								
After short vowel	7	23.2	10	21.1	16	17.9	3	28.3
After long vowel	1	10.0	15	12.4	5	13.4		
Ambiguous	1	12.0	39	12.1	14	12.7		
Initial								
Utterance-initial	17	11.9	44	9.0	40	8.8	70	10.4
(Not measurable)	(37)		(58)		(41)			
V + C stressed	47	7.3	45	5.4	107	5.3	40	10.8
unstressed	6	4.5	18	3.4	6	3.3	25	7.7
C + C stressed	43	6.8	23	6.4	108	6.1	28	11.5
unstressed	1	4.0	22	3.2			7	8.3
Syllable-initial (2. member of cluster)								
Quantity 1	9	3.9	101	4.5	59	4.2	42	9.0
Quantity 2			2	8.3				
Quantity 3	3	17.0	6	23.0	5	21.4	2	25.0
Final								
Utterance-final								
Short	14	6.1	52	5.9			53	13.7
Long			6	25.3	3	31.0		
Ambiguous			3	17.3	4	13.8		
C + V short	3	4.7	21	3.2			13	9.9
long	2	25.5			2	20.0		
ambiguous					3	6.0		
C + C short	39	5.1	55	5.3	1	6.0	62	8.2
long	2	16.0	4	11.0	1	4.0	4	11.8
ambiguous			7	9.3				
Syllable-final (1. member of cluster)								
Short	3	4.0	20	4.7	12	4.0	22	8.9
Long	2	18.0	12	14.0	4	10.9	17	13.3

median value of 5 csec. An example of /p/ in quantity 1 is given on Figure 5, which contains the word paber (utterance 404). With 4 csec, this is one of the shorter occurrences; it is typically voiceless and unaspirated.

3.1.2. Intervocalic /p/ in quantity 2

This allophone was manifested in six instances, with an average duration of 10.3 csec. The range of durations was from 7 to 14 csec, with a median value of 10 csec. The duration of the allophone in quantity 2 appeared to be connected with the length of the word: the shortest allophones (7 and 8 csec) were associated with the polysyllabic words lõpetatakse (60) and õpetaja (224), the longest (14 csec) allophone occurred in the disyllabic word kapi (30). Examples of /p/ in quantity 2 are given on Figure 1, which contains the word kapi (30), and on Figure 3, which contains the word kipitab (251), in which /p/ had the duration of 10 csec.

An interesting question is the difference between the one occurrence of /p/ in quantity 1 having a duration of 7 csec (in the word hobune, utterance 273), and the one occurrence of /p/ in quantity 2 with a duration of 7 csec (in the word õpetaja, utterance 224). Neither word is in what could be considered unstressed position;[8] however, the word hobune is last in its sentence, whereas the word õpetaja constitutes the first word of the utterance. It also has one more syllable, and the duration of quantity 2 plosives appears to decrease with increasing length of the word. In sentence-final position, a certain amount of lengthening was found in numerous other instances.

Although the allophones of /p/ in the two words had the same duration, from the point of the listener there was no question about the phonemic assignment of the allophones of /p/ to quantity 1 in the word hobune and to quantity 2 in the word õpetaja. A possible difference in the degree of articulatory tension was not directly reflected on the spectrograms. It is probable that in the word hobune the half-long vowel of the second syllable helps establish the first syllable as short. The half-long vowel was not present in õpetaja; however, the second syllable of this word was closed because of the following /t/, and thus the two cases are not directly comparable. The presumed syllable boundary in /p/ in quantity 2 was not indicated on the spectrogram in any way. Phonetic factors in addition to the duration of the plosive gap must have been present which make the assignment of /p/ to quantity 1 or 2 possible.

3.1.3. Intervocalic /p/ in quantity 3

There were eight occurrences of intervocalic /p/ in quantity 3, with an average duration of 21.6 csec. The range of durations in this case was considerable; the shortest overlong /p/ had the duration of 10 csec, the longest 34 csec. The median value was 22 csec. Here, and in other words of this kind, the allophonic variation in duration appeared to depend partly upon the duration of the vowel preceding the consonant in quantity 3. The duration of 10 csec occurred in the word hoopis (393), in which the first vowel was overlong. In all other instances, /p/ in quantity 3 was preceded by a vowel in quantity 1.

With 10 csec, the segmental duration of /p/ in this manifestation of the word hoopis fell within the range of /p/ in quantity 2, whose average duration in this set of data was 10.3 csec. The duration of /o/ was 11 csec. The durations of vowels in this set of sentences have not been measured and tabulated systematically; however, in such a word as kooli (15), the speaker used a vowel with a duration of 26 csec. The duration of /o/ in hoopis is thus too short to make it possible to associate the 'overlength' of the syllable with the vowel rather than with the consonant. As the 'overlength' cannot be due to the segmental quantities of either /o/ or /p/, it becomes obvious that syllabic quantity is determined by the interaction of the durations of the segmental sounds and the placement of the syllable boundary.[9]

The intermediate durations, 12 and 15.5 csec, occurred in trisyllabic words. All disyllabic words with a short vowel in the first syllable had durations of /p/ of 20 csec or above. The longest value, 34 csec, occurred in the utterance-final word tuppa (398).

An example of /p/ in quantity 3 is given on Figure 4, which contains the word hüppas (276), with /p/ duration of 20 csec.

3.1.4. Intervocalic /p/ of ambiguous duration

There are certain positions beyond the boundary between the first and the second syllable in which consonants may occur in contrastive quantities. In certain instances, it is subjectively possible to assign these to one of the three phonemic quantities; concrete examples will be discussed in connection with other consonants, since no examples with /p/ were present in the corpus. In the position between the second and the third syllable, after a first syllable in either quantity 1 or 2, a consonant may appear as either short or long. The short duration appears identical with phonemic quantity 1; the long duration is somewhat

ambiguous. This writer, at least, has never been able to assign it to either quantity 2 or quantity 3 with any degree of assurance. Needless to say, there is no contrast between quantities 2 and 3 in this position.

The 500 sentences contained only one example of /p/ in this position: the word sinepit (248), in which the duration of /p/ was 12 csec. Its duration thus fell within the area of overlap between the longest quantity 2 allophones and the shortest quantity 3 allophones. The word sinepit (248) is shown on Figure 3.

3.2. Initial /p/

3.2.1. Utterance-initial /p/

It is, of course, difficult to determine the duration of utterance-initial voiceless plosives by acoustic-phonetic methods. There were, nevertheless, a number of instances in which some indications were found on spectrograms on which a cautious measurement could be based. In numerous cases, an utterance appeared to be preceded by breath noise, which ceased for a period before the explosion of the consonant; the duration of this period without breath noise may be assumed to represent the duration of the closure of the consonant. In other instances, the spectrograms showed a spike preceding the explosion by something like 10 csec; since a considerable amount of amplification was used in the production of the broad-band spectrograms, it is quite possible that these spikes represent a kind of weak percussion noise produced by the formation of the closure (the implosion) in the articulation of the plosive consonant. There were 17 instances in the case of /p/ in which such observations could be made; the average duration of /p/ in these instances was 11.9 csec. In 37 instances, any indication of the duration of an utterance-initial /p/ was lacking.

Examples of initial /p/ whose duration could not be measured appear on Figure 5, in the utterance beginning with pange (404), and on Figure 7, in the utterance starting with puusliku (495).

3.2.2. Word-initial /p/ following a word ending in a vowel

The duration of word-initial consonants appears to be influenced, to a certain extent, by the relative amount of sentence stress the words carry. In the case of /p/, most words beginning with /p/ appeared to be stressed; there were only six words beginning with /p/ that were classified as unstressed.[10] The 47 occurrences of /p/ as the initial consonant of stressed words had an average duration of 7.3 csec; the average duration of /p/ at the beginning of six unstressed words was 4.5 csec. The range for allophones of /p/ beginning stressed words was from 4 csec to

10.5 csec, with 30 of the 47 values concentrated between 6 and 8 csec, and a median of 7 csec. The longest value occurred in the stressed monosyllabic word pöab (138); the shortest values probably represent relatively lesser degrees of stress. The values of initial /p/ of unstressed words ranged from 3.5 to 5 csec, with 4.5 csec as the median value.

In the word õunapuud (343), the duration of the allophone of /p/ starting the second member of the compound was 18 csec. This duration is obviously outside of the range of values associated with word-initial /p/. It is evident that the structure of this originally compound word now resembles the phonological pattern of words like sinepit, discussed above, in which the duration of the plosive is noncontrastively long.[11]

Numerous examples of word-initial /p/ are contained in the illustrations. Figure 1 contains word-initial /p/ in the compound kassipoeg (50), where /p/ had a duration only slightly shorter than the average (6.5 csec). The phonological fusion of the two components of the compound has evidently not taken place in this word in a degree comparable to that found in õunapuud. Figure 1 also contains the word põrand (36), with /p/ duration 9 csec, and the word pea (116), with /p/ duration 9 csec. Figure 3 contains the word põlv (251), with /p/ duration 10 csec; Figure 5 shows the word panna (439), with /p/ duration 6 csec, and Figure 6 the word peab (485), with /p/ duration 5 csec. Both of the last-mentioned words were relatively unstressed in their respective utterances, and were preceded by a word with relatively greater sentence stress. In Figure 7 the word puutikk (500) had an initial /p/ with a 7 csec duration.

3.2.3. Word-initial /p/ following a word ending in a consonant

In the 43 measurable instances of sequences of words ending in a consonant, followed by a word beginning with /p/, the average duration of /p/ was 6.8 csec. In one occurrence of an unstressed word beginning with /p/, the duration of /p/ was 4 csec. The range of durations of /p/ in stressed words was from 3.5 csec to 11 csec, with 23 out of 43 durations clustering around 6-7 csec, and a median value of 7 csec. In the case of word-initial /p/ following a word ending in a consonant, a regular segmental conditioning of the duration could be observed: practically all the instances with durations of less than 6 csec consisted of sequences in which the first word ended in a nasal.

Six instances of /p/ in this position are contained on the illustrations. Figure 3 contains the word sequence sinepit peale (248), in which /p/ started a stressed word and had the duration

of 9.5 csec. Figure 4 contains the sequence on pikad (296), in which /p/ had the duration of 4.5 csec. On the same figure, the sequence on pikk (300) had a /p/ with 6 csec duration. The word pikk is here in final position. Figure 5 contains the sequence uus paber (404), with /p/ duration 7 csec. Figure 6 contains the sequence kummardasid puuslikku (493), in which case the duration of /p/ was not measurable; the total duration of the /t/ + /p/ sequence was 14.5 csec. Figure 7 contains the sequence silmad põlesid (495), in which the duration of /p/ was 9.5 csec.

There were three other sequences in which the duration of the individual components was not measurable. These were the sequence lapp peale (134), with a total duration of 31 csec for the gap corresponding to the /p/ + /p/ sequence; the sequence kõigutab puude (154), with a plosive gap duration of 15 csec, and the sequence kardab parmu (278), in which the /p/ + /p/ duration was 18.5 csec.

3.2.4. Syllable-initial /p/ as second member of an intervocalic cluster

The occurrence of word-initial /p/ after words ending in a consonant may be directly compared with the occurrences of /p/ in clusters, where a syllable boundary precedes the allophone of /p/. The problem of consonant clusters is rather complicated, since in some intervocalic clusters plosives may occur in the different phonemic quantities, and if the plosive as second member of a cluster occurs in quantity 2 or 3, the syllable boundary falls within the hold of the consonant.

There were nine instances in which /p/ in quantity 1 started the second syllable, following a syllable ending in a consonant. The average duration of /p/ under such positional conditions was 3.9 csec. Five of the nine words contained the cluster /m/ + /p/; the average duration of /p/ starting the second syllable after a first syllable ending in /m/ was 3 csec, while in the other four instances it was 5.9 csec.

The material contained three clusters of consonant + /p/ in quantity 3. The average duration of /p/ in these words was 17.0 csec, the individual values being 14, 18, and 19 csec.

The illustrations contain four examples. Figure 3 contains the utterance kaks kirpu on karbis (275), in which the intervocalic cluster /r/ + /p/ appears with /p/ in quantity 3 in the word kirpu (19 csec) and in quantity 1 in the word karbis (6 csec). Figure 4 contains the word lambi (300), and Figure 5 the word ümber (404). In both instances /p/ followed a nasal and had the duration of 3 csec.

3.3. Final /p/

3.3.1. Utterance-final /p/

The duration of utterance-final voiceless plosives was unambiguously measurable in every case, since each occurrence was released with a clearly visible spike. There were 14 instances of final occurrences of /p/ in the corpus, all of which were phonemically short. The average duration of /p/ in these utterances was 6.1 csec, with extreme values of 4 and 8 csec, eleven out of 14 values clustering around 6 - 7 csec, and a median duration of 6 csec, One example of final /p/ is presented on Figure 3, which contains the word kipitab (251). Here the utterance-final allophone of /p/ in quantity 1 had the duration of 6 csec.

3.3.2. Word-final /p/ followed by a word beginning with a vowel

The test material contained five instances in which a word ending in /p/ was followed by a word beginning with a vowel. In three instances, the /p/ was short; the average duration of these occurrences was 4.7 csec, ranging from 3 to 6.5 csec. The two occurrences of a monosyllabic word with a short vowel and long /p/ had the durations of 25 and 26 csec, i.e. an average of 25.5 csec, for /p/ in quantity 3. An example of each type is offered in the illustrations. Figure 1 contains the sequence kepp on (30), in which /p/ had the duration of 26 csec. Figure 6 contains the sequence annab armu (454), with /p/ duration of 5 csec.

3.3.3. Word-final /p/ followed by a word beginning with a consonant

There were 39 instances in which a word-final short /p/ was followed by a word beginning with a consonant. The average duration of /p/ in these words was 5.1 csec. The range was from 3 to 8 csec; 25 of the values clustered between 4 and 6 csec, and the median value was 5 csec. In two instances the word-final /p/ was in quantity 3; these two occurrences had the values 12 and 20 csec. The value of 12 csec occurred in the sequence taktikepp käes (163). The word kepp here constitutes the second member of a compound word and thus does not have the same relative degree of stress as in the other instance, the sequence kepp seisab (448).

The case of sequences of word-final /p/ followed by word-initial /p/ was discussed above under word-initial allophones of /p/. There was one other instance in which the duration of word-final /p/ could not be measured: the sequence tuleb kokku (385), in which the plosive gap corresponding to the sequence /p/ + /k/ had a total duration of 14 csec.

Figure 1 contains an example of word-final short /p/, the sequence püüab vurri (50), in which the duration of /p/ was 6.5 csec. The sequence taktikepp käes (163), shown on Figure 2, was discussed above. Figure 6 contains the sequence peab seda (485), where /p/ occurred in an unstressed sequence and had the duration of 4 csec.

3.3.4. Syllable-final /p/ as first member of an intervocalic cluster

Sequences of word-final /p/ followed by a word-initial consonant are directly comparable to such occurrences in which /p/ constitutes the last sound preceding a syllable boundary, followed by a syllable beginning with a consonant. Intervocalic clusters with /p/ as first element occurred five times in the corpus. In three of these instances /p/ was short; there were two cases in which /p/ was overlong. The durations of the short syllable-final allophones of /p/ were 3, 4, and 5 csec; the two long occurrences had values of 17 and 19 csec. An illustration of a short occurrence is offered on Figure 2, which contains the word lapsed (149), where /p/ had the duration of 5 csec.

4. Allophones of /t/ and /t'/

For the purposes of this study, /t/ and palatalized /t'/ are treated together. As has been pointed out in a previous publication,[12] these phonemes contrast in certain positions, primarily in word-final position, and are in complementary distribution in other positions. The contrast is manifested, in acoustic terms, in a difference in the terminal frequencies of formants in transition toward the two dental plosives. As far as the duration of the closure is concerned, the assumption is made in the present paper that any possible differences between allophones of /t/ and /t'/ will not be significant. The symbol /t/ will be used from now on to refer to both phonemes.

4.1. Intervocalic /t/

4.1.1. Intervocalic /t/ in quantity 1

The material contained a considerably greater number of occurrences of allophones of /t/ than occurences of allophones of /p/. Table I presents the average duration of 50 occurrences of /t/ in quantity 1 between the first and the second syllable. The average and the median value was 3.0 csec. The durations ranged from 2 to 5 csec in those cases in which the duration of /t/ was measurable, 23 of the 50 occurrences having the value of 3 csec. The longest durations occurred in words where /t/ followed a vowel or diphthong in quantity 3; in 13 such occurrences, the

average duration of /t/ in quantity 1 was 4 csec. The two instances of 5 csec duration occurred in the words lööda (19) and süüdi (21), both of which were also the last words in their respective utterances. Thus the position of the word with regard to the end of the utterance again influences the duration of the segmental sounds.

The shortest manifestations occurred in unstressed words like seda and teda, where the duration of the vowel of the first syllable was extremely short (with an average of 2 csec), and where in several instances the allophone of /t/ was either fully voiced or a partially voiced fricative. The average duration of the allophone of /t/ in twelve such occurrences was 2 csec; there were five instances in which a fricative occurred, and two instances in which the duration of /t/ could not be determined because the sequence expected to contain /t/ appeared fully voiced, and there was no indication of the presence of a plosive consonant. Such brief voiced or fricated manifestations of /t/ in quantity 1 appeared also in words with a greater degree of sentence stress and with a vowel in quantity 2 in the first syllable preceding intervocalic /t/. No allophones of this kind were observed in words with a vowel in quantity 3 in the first syllable.

In two of the occurrences of seda, the vowel of the first syllable appeared to have been omitted, while the half-long vowel of the second syllable was quite prominently present. An example of an occurrence of this type is shown on Figure 6, which contains the word seda (485). Utterance 116, presented on Figure 1, contains two occurrences of intervocalic /t/ in quantity 1 in the sequence köidikud teda. In both instances, the brief period of closure was followed by a clear plosive release; the allophone following the diphthong in quantity 2 was actually shorter than the allophone following the vowel in quantity 1. A slightly longer manifestation of intervocalic /t/ in quantity 1 occurred in uude (401), shown on Figure 5. In this word, /t/ follows a vowel in quantity 3, and there is no trace of voicing or frication during the plosive gap.

Occurrences of intervocalic /t/ in quantity 1 at the boundary of syllables beyond the first and second are not included in the table, but they will be briefly discussed here. There were 16 cases in which this allophone occurred between the second and the third syllable. The average duration was 3.4 csec; the range was from 2 to 5 csec, with 9 out of 16 occurrences between 3 and 4 csec, and a median of 3 csec. The two occurrences with 5 csec occurred in koguda (385) and elada (418), both of which were the last words in their respective utterances. Several of the shortest realizations were fully voiced, but recognizable on the spectrograms

by the presence of a plosive gap. Examples of /t/ at the boundary between the second and third syllable are given on Figure 1, containing the word mattidega (36), and on Figure 4, containing the word kukkuda (390). In mattidega, the 3 csec long /t/ was fully voiced; in kukkuda the allophone of /t/ was 3.5 csec long and had a relatively more prominent release.

Intervocalic /t/ occurred four times in quantity 1 between the third and fourth syllable. The average duration of these occurrences was 3.5 csec; they ranged from 2.5 to 4 csec.

4.1.2. Intervocalic /t/ in quantity 2

There were 20 instances in which intervocalic /t/ occurred in quantity 2 between the first and second syllable. The average duration of these occurrences was 8.3 csec; the median value was 8 csec, and 14 of the 20 occurrences fell between 7.5 and 8.5 csec. The extreme values appeared to be influenced by position within the utterance and relative degree of sentence stress. The longest value (14 csec) occurred in kata (383), which was the last word of the utterance; the next longest duration (12 csec) occurred in katusel (17), likewise the last word of the utterance, but trisyllabic. The shortest value (5.5 csec) occurred in jääte (486), the only word in the group of 20 in which the vowel preceding the /t/ in quantity 2 was also in quantity 2. In all other instances the vowel was in quantity 1. The first syllables of words containing a plosive in quantity 2 at the boundary between the first and second syllable are in syllabic quantity 2, regardless of whether the vowel of the first syllable is in quantity 1 or 2. A certain amount of downward adjustment in the segmental quantity of the consonant appears to take place to compensate for the greater length of the vowel; but the syllabic quantity is unambiguously manifested.

There were nine instances in which intervocalic /t/ occurred in quantity 2 between the third and fourth syllable. In this position, many consonants may occur in any one of the three significant quantities, and no ambiguity exists in determining to which quantity the consonant belongs. The average in these nine cases was 7.2 csec, the range from 6 to 8 csec. In two instances (in the words viisakusetust [74] and parandamatu [76]) intervocalic /t/ occurred between the fourth and the fifth syllable in words which the speaker produced with secondary stress on the fourth syllable; the durations were 6.5 and 8 csec, and the subjective impression of the presence of phonemic quantity 2 appears to be borne out by the measured durations of the segments.

As was mentioned above, the position between the second and third syllable is one of a certain degree of indeterminacy.

In words with a first syllable in quantity 1 or 2, the consonant may either appear in quantity 1 or in a duration which is subjectively felt to be long, but which cannot be unambiguously assigned to either quantity 2 or 3. However, in words with a first syllable in quantity 3, it appears that plosives occurring between the second and third syllable may also be in all three quantities. In other words, a contrast between consonant quantity 2 and 3 is possible in these words, whereas in words with a first syllable in either quantity 1 or 2 there is no such contrast. The material contained the three words aastate (70), tundmatu (496), and tundmatut (497), in which /t/ between the second and third syllable had the durations of 10, 8.5, and 8 csec respectively. The average duration of 8.8 csec supports the assignment of these occurrences to quantity 2 on a perceptual basis rather than to the indeterminate quantity.

Examples of /t/ in quantity 2 are offered on Figure 1, which contains the word kata (36), where /t/ was 8 csec long; and on Figure 7, containing the words tundmatu (496) and tundmatut (497) discussed above.

4.1.3. Intervocalic /t/ in quantity 3

There were 25 occurrences of intervocalic /t/ in quantity 3 between the first and the second syllable. In ten instances, /t/ in quantity 3 followed a vowel in quantity 1; the average duration of these occurrences was 21.1 csec, the median 18 csec. The durations ranged from 8 csec to 36 csec. The average of 21.1 may be relatively insignificant in view of the wide range of occurrences; therefore it appears advisable to consider some of the values separately. The three shortest occurrences (8, 8.5, and 10 csec) were found in three productions of the word võttis (utterances 316, 360, and 412), in each of which the word occurred in a relatively unstressed position between two words with a greater degree of sentence stress. Two of the three intermediate values, 13 and 18 csec, occurred in the relatively long words ettevaatamatuse (65) and mattidega (36). The third intermediate value, 14 csec, occurred in the word ratta (447), which was first in the utterance and preceded the word with main stress. The four longest values were associated with stressed disyllabic words occurring in final position. The actual durations of /t/ were as follows: katta (384), 33 csec, ette (408), 34 csec, kotti (37), 36 csec, and juttu (147), 36 csec. Sentence stress and position within the utterance thus appear to affect manifestations of plosives in quantity 3 in a relatively high degree.

The test materials also contained 15 words in which /t/ in quantity 3 followed a first syllable with an overlong vowel or

diphthong.[13] In these instances the average duration of the consonant was 12.4 csec. The range was from 7 to 28 csec; thus with regard to the range of the extreme durational values, there appears little difference between the manifestations of /t/ in quantity 3 following a short or a long vowel. A considerable amount of difference, however, was found in the distribution of the values around the median value, which in this case was 10 csec. Twelve out of the 15 utterances had values between 10 and 13 csec. The one instance in which /t/ was shorter than 10 csec occurred in näitas (227), in which the word occurred between two words with considerably greater sentence stress, and /t/ had a duration of 7 csec. The two occurrences in which /t/ was considerably longer than the median were saata (382), 24 csec, and lauta (79), 28 csec. Both words were final in their respective utterances. These two extremely long durations also account for the fact that the average duration is noticeably greater here than the median duration.

There was also one instance in which intervocalic /t/ occurred between the third and fourth syllable in what appeared to be quantity 3 according to perceptual judgment. In this word, vastamata (66), the secondary stress was on the third syllable, and /t/ had the duration of 25.5 csec. The considerable length of the manifestation of /t/ may be partly due to the fact that the word was last in the utterance.

In another word, maksmata (218), the duration of /t/ was 21.5 csec, and the manifestation of /t/ was felt to belong to quantity 3 in the same way as in the word vastamata. Although /t/ here occurs between the second and third syllable, it is possible to assign this duration to phonemic quantity 3, since the first syllable of maksmata is in overlong syllabic quantity.

Examples of intervocalic /t/ in quantity 3 are offered on Figure 1, containing the word mattidega (36), in which /t/ duration was 18 csec, and Figure 2, containing the word juttu (147), with /t/ duration 36 csec.

4.1.4. Intervocalic /t/ of ambiguous duration

As was mentioned before, the position between the second and third syllable may be ambiguous: if the first syllable is not overlong, there is no contrast between consonant quantities 2 and 3 in that position. The corpus of utterances contained a considerable number of occurrences of /t/ in this ambiguous quantity. The average duration of 39 such occurrences was 12.1 csec. The range of occurrences was from 6 to 25.5 csec; the median value was 11 csec, and 19 out of 39 durations fell between 8 and 14 csec. The values were spread over a considerable range, and

the concentration around the median was less clearly defined than, for example, in the case of /t/ in quantity 3 following an overlong vowel or diphthong. Nevertheless, some conditioning factors could be discovered for both the shortest and the longest occurring values. The three durations of 6 and 6.5 csec occurred in the words lõpetatakse (60), ratsutada (203), and meelitatakse (413); clearly the total length of the word has an influence on the manifestation of the durations of the individual segments. The longest values, from 18 to 25.5 csec, occurred in utterance-final words.

There were also several instances in which a spike could be observed within the plosive gap, corresponding to a subjective kinesthetic impression of rearticulation of the plosive.[14]

Illustrations of /t/ in the position between the second and the third syllable are contained on several of the figures. Figure 3 contains the word kipitab (251), where /t/ had the duration of 15 csec. Figure 6 contains the word niisuta (458), with /t/ duration 8 csec. Figure 7 contains two occurrences of the word huvitav in utterance-final position (498 and 500); the durations were 16 and 14.5 csec respectively, and the first of the two productions (498) also shows the spike within the gap which was sometimes observed in those productions that were felt to be rearticulated more distinctly than others.

4.2. Initial /t/

4.2.1. Utterance-initial /t/

The difficulties inherent in attempting to measure utterance-initial manifestations of voiceless plosives were mentioned in connection with utterance-initial /p/. With considerable reservations, tentative measurements could be made in 44 instances, in which the average duration of /t/ was 9.0 csec. There were 58 instances in which the duration of utterance-initial /t/ could not be measured with any degree of accuracy. In a few instances, however, the spike presumed to be associated with the formation of the closure for the initial plosive could be seen quite clearly. Three such cases are included on the figures. Figure 2 contains an utterance-initial /t/, 9 csec long, in the word tal (163). The word tirtsul (296), displayed on Figure 4, and the word too (443) shown on Figure 5, both had an initial /t/ with a duration of 10 csec.

4.2.2. Word-initial /t/ following a word ending in a vowel

The test materials contained 63 instances in which a word ending in a vowel was followed by a word beginning with /t/.

These occurrences were roughly classified into stressed and unstressed instances: the word beginning with /t/ had either at least a minimal amount of sentence stress, or constituted an unstressed part of the utterance. In many instances, these unstressed words beginning with /t/ were forms of the personal pronoun of the third person singular, tema, used in the shorter form ta; in these cases, the perceptual impression of lack of stress was supported by the selection of the short form of the pronoun. In 45 stressed occurrences, the average duration of initial /t/ was 5.4 csec; in 18 unstressed occurrences, the average duration of allophones of /t/ was 3.4 csec. The range for the stressed occurrences was from 3 to 8 csec, with a median value of 5.5 csec and 38 out of 45 occurrences falling between 4 and 6.5 csec. The shortest durations were observed in the sequences ega täna (352), 3 csec, and ta tahtis (354), 3.5 csec. (Utterance-initial /t/ was not measurable.) In both of these instances, the word beginning with /t/ was perceived as having a noticeable degree of stress.

The range for the unstressed occurrences was from 2 to 4.5 csec, with a median value of 3.5 csec and 15 out of 18 occurrences falling between 3 and 4 csec. The shortest of the unstressed initial allophones of /t/ were fully voiced or had a slight fricative quality. It is worth mentioning that in the group of the subjectively unstressed occurrences were also the initial consonants of the second components of the compounds kurjategija (76) with 3.5 csec, lõunatund (93) with 3 csec, and puutikku (491) with 4 csec.

Examples of initial /t/ following a word ending in a vowel are presented on Figure 1, which contains the sequence kapi taga (30), with 4.5 csec; Figure 4, containing the sequence lambi taht (300), 6 csec; Figure 6, containing the sequence keegi teine (485), 5 csec; and Figure 7, with the sequence puutikk (500), in which /t/ had the duration of 5.5 csec.

4.2.3. Initial /t/ following a word ending in a consonant

In the 45 instances of such sequences, 23 words beginning with /t/ were classified as having a greater or lesser degree of sentence stress, while 22 were classified as unstressed. The unstressed group consists again almost exclusively of forms of the third person singular pronoun, where the lack of stress is also reflected in the selection of the shorter form of the pronoun.

In the 23 stressed occurrences the average duration of initial /t/ following a consonant was 6.4 csec. The range was from 3 csec to 11.5 csec; the median value was 6.5 csec, and 14 out of 23 durations were concentrated between 6 and 8 csec. It was observed previously that particularly short allophones of initial

plosives occurred after nasals. The sequence /n/ + /t/ accounts for all six occurrences of durations between 3 and 5 csec. The relatively short allophone of /t/ occurred in all /n/ + /t/ sequences, regardless of the fact that the word beginning with /t/ was perceptually classified as stressed.

The material also contained ten instances in which a word ending in /t/ was followed by a word beginning with /t/. In one of these instances (in the sequence paremad töötingimused [483]) the rearticulation of the word-initial /t/ appeared acoustically manifested as a spike on the broad-band spectrogram. In the other nine instances, the duration of the individual components of the /t/ + /t/ sequence could not be determined.

The unstressed occurrences had an average duration of 3.2 csec. The range was from 2 to 5 csec, with a median value of 3 csec, and 20 out of 22 durations having values between 2 and 4 csec. The shortest instances followed words ending in /n/ (such as the sequence on ta in utterances 253, 255, and 328); however, in these instances the brief allophone was not completely voiced, and had a prominent release.

Examples of initial /t/ following a word ending in a consonant are offered on several figures. Figure 1 contains the sequence köidikud teda (116), in which the individual components of the /t/ + /t/ sequence cannot be separated, and the total duration of the plosive gap is 11 csec. Figure 2 contains the sequence on taktikepp (163), in which initial /t/ follows the word on, and the duration of initial /t/ is 3 csec, although the word carries primary sentence stress. Figure 3 contains the sequence on terav (264), where /t/ again has the duration 3 csec, regardless of the primary sentence stress on terav. Figure 7 contains the sequence uuris tundmatut (497), where the duration of initial /t/ was 5.5 csec.

4.2.4. Syllable-initial /t/ as second member of an intervocalic cluster

The test materials contained a considerable number of clusters, in which /t/ appeared as last member. In instances where /t/ was in turn followed by a vowel, the allophone of /t/ started the syllable. Only those instances are considered in the present context in which a single consonant closed the first syllable, while /t/ started the next syllable. There were 101 such occurrences, with an average duration of 4.5 csec. The range of durations was from 1.5 to 12 csec, with a median value at 4 csec, and 77 out of 101 instances falling between 3 and 6 csec.

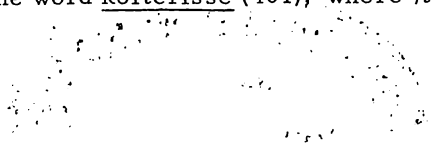
The wide range of durations is partly explainable by segmental environment. Without exception, the durations of 1.5 and 2

csec and most of the durations of 3 csec occurred in clusters of /n/ + /t/. At the other extreme, there was one duration of 12 csec in the word takti (162), which occurred in final position, and one duration of 10 csec in halvasti (235), likewise in final position. All other durations were below 8 csec. In the /n/ + /t/ sequences there was one case (the word randa [324]) where no manifestation of /t/ could be observed on the spectrogram.

In some of the consonant + /t/ clusters included in this set of 101 utterances the duration of /t/ was invariable (for example, in clusters consisting of /h/ + /t/ and /k/ + /t/). There are a number of clusters in which /t/ in quantity 1 may contrast with /t/ in quantities 2 and 3. Occurrences of such clusters with /t/ in quantity 1 were also included in the present set of 101. Clusters with /t/ in quantity 2 in intervocalic position are relatively rare; only two examples were contained in the 500 utterances. Of these, the word parte (391) had a /t/ with 9 csec duration, and the word tuulte (229) a /t/ lasting for 7.5 csec. These durations fall clearly within the range of the other occurrences of /t/ in quantity 2 in intervocalic position: the average of 20 productions of /t/ in quantity 2 was 8.3 csec, which happens to correspond exactly to the mean of these two productions.

Clusters with /t/ in quantity 3 in intervocalic position occurred in six words. The average duration of /t/ in these six productions was 23.0 csec; the range was from 13 to 31 csec. There were two clearly distinguishable groups. Two of the instances occurred in polysyllabic words: pintadega (194), 13 csec, and korterisse (401), 14 csec. The other four words were disyllabic: konti (198), where /t/ had a duration of 28 csec, with a weak spike at 20 csec; konte (239), 25 csec; sülti (247), 27 csec, with a spike at 22 csec, and parti (271), 31 csec. All these occurrences were in final position within their respective utterances. This situation parallels closely the findings in the case of intervocalic /t/ in quantity 3, following a first syllable with a short vowel.

Examples of clusters with /t/ as second member are given on several of the illustrations. Figure 2 contains the word taktikepp (163), in which /t/ beginning the second syllable has a duration of 4.5 csec. Figure 3 contains the word süldile (248), where /t/ has the duration of 3 csec. It should be remembered that /l/ + /t/ is one of the clusters in which /t/ may occur in all three quantities, and the manifestation here is quantity 1 rather than the invariable syllable-initial manifestation as in the previous word. Figure 4 contains the word ähvardas (390), where /t/ is again in phonemic quantity 1; the duration is 4 csec. Figure 5 contains the word korterisse (401), where /t/ occurs in quantity 3



with a duration of 14 csec. Figure 6 contains the words kohtunik (454) and nuustiku (494), with /t/ durations of 6 and 4.5 csec. Figure 7 contains the words luustiku (496), /t/ - 7.5 csec, luustikku (497), /t/ - 6 csec, and luustik (498), /t/ - 5 csec.

4.3. Final /t/

4.3.1. Utterance-final /t/

The analyzed material contained three types of utterance-final /t/: quantity 1, quantity 3, and long /t/ in a quantity that could not be immediately assigned to either quantity 2 or quantity 3. The most numerous group in the material consisted of /t/ in quantity 1. The 52 instances of this type had an average duration of 5.9 csec. The median value was 6 csec; the range was from 4 to 8 csec, with 41 out of 52 instances clustering between 5 and 7 csec. In all these cases, final /t/ in quantity 1 was voiceless and had a clearly detectable spike release, with no noticeable aspiration.

There were six instances in which a monosyllabic word, ending in /t/ in quantity 3, constituted the last word of the utterance. The average duration of these occurrences was 25.3 csec; the range was from 16.5 to 30 csec, and the median value between 25 and 27 csec. The 16.5 csec long occurrence was measured in the word koot (192), where the vowel was in quantity 3; the next shortest duration (24 csec) occurred in niit (362), in which the vowel preceding /t/ in quantity 3 was likewise in quantity 3. In the four words in which the vowel was in quantity 1, the duration of /t/ was 25, 27, 29, and 30 csec.

There were three words in which /t/ occurred in final position in a quantity that could not be identified perceptually either with quantity 2 or quantity 3. In the word alet (397), /t/ had the duration 23.5 csec; in tahvlit (178), the duration of final /t/ was 14 csec, and in pliiatsit (187) the duration of /t/ was 14.5 csec.

Illustrations of utterance-final /t/ in quantity 1 are given on Figure 2, containing the word väsinud (149), with /t/ duration 6.5 csec; on Figure 4, containing the word jalad (296), /t/ duration 6 csec, and on Figure 7, containing the word põlesid (495), in which final /t/ had the duration of 5 csec.

4.3.2. Word-final /t/ followed by a word beginning with a vowel

The 500 utterances contained 21 instances in which a word ending in /t/ in quantity 1 was directly followed by a word beginning with a vowel. The average duration of these manifestations of /t/ was 3.2 csec. The range was from 2 to 4.5 csec, with 13 out of 21 occurrences between 3 and 4 csec, and a median value

of 3 csec. There were four instances in which the word-final /t/ appeared as a partly voiced fricative.

Fifteen of the sequences consisted of a word ending in /t/ followed by the word on, which was classified as unstressed in these sequences. A separate average for these occurrences of /t/ yielded a duration of 2.9 csec.

An example of word-final /t/ followed by a word beginning with a vowel is offered on Figure 2, containing the sequence lapsed on (149), in which /t/ had the duration of 2.5 csec and appeared fully voiced.

4.3.3. Word-final /t/ followed by a word beginning with a consonant

There were 55 instances in which a word-final /t/ in quantity 1 occurred before a word beginning with a consonant. In these instances the average duration of the allophones of /t/ was 5.3 csec. The range was from 2 to 10 csec; the median was 5 csec, and 31 out of 55 occurrences had values between 4 and 6 csec. The duration of /t/ was shortest in unstressed pronouns such as nad and need.

There were four instances in which word-final /t/ occurred in quantity 3. The average duration of these occurrences was 11.0 csec. This time there appeared no difference between /t/ following a short vowel and /t/ following a long vowel: the range was from 10 to 13 csec, embracing two occurrences of long vowel + /t/ in quantity 3 and two occurrences of short vowel + /t/ in quantity 3. However, the word ending in /t/ seemed to carry relatively little sentence stress in each of these instances.

There were also seven instances in which a long final /t/ occurred in words of two or three syllables, in which case the quantity is not always immediately obvious. The average duration of these seven occurrences of /t/ was 9.3 csec; their range was from 7 to 10.5 csec, with a median of 10 csec and all values clustering remarkably close to the median.

Examples of /t/ in final position followed by a word beginning with a consonant are given in several illustrations. Figure 3 contains the sequence keset koske (172), in which /t/ appears in the ambiguously long quantity at the end of the second syllable, having a duration of 10.5 csec. The same figure contains the sequence sinepit peale (248), where the ambiguously long /t/ had a duration of 9 csec. On Figure 4 the sequence pikad jalad (296) contains a word-final /t/ in quantity 1, with a duration of 4 csec. Figure 6 contains the utterance nad kummardasid puuslikku (493), in which the first unstressed /t/ (in nad) had the duration 3.5 csec; the gap representing the sequence /t/ + /p/ between the

second and third word contained no spike which would have indicated the release of the first plosive. Figure 7 contains the sequence silmad põlesid (495), in which the final /t/ of the first word had a duration of 9 csec, and the sequence tundmatut luustikku (497), where /t/ was in an ambiguously long quantity and had the duration of 10 csec.

4.3.4. Syllable-final /t/ as first member of an intervocalic cluster

In the test utterances there were 32 intervocalic occurrences of clusters consisting of /t/ + consonant. In 12 of these cases, /t/ occurred in overlong quantity, with an average duration of 14.0 csec. The range of the durations was from 8.5 to 27 csec; the longest values occurred in such words as latvu (154), 27 csec, katku (146), 18 csec, and katki (133), 18 csec. All three words had a vowel in quantity 1 in the first syllable; all were also last in their respective utterances. The other instances either had long vowels or diphthongs before the syllable-final /t/, or occurred in non-final positions within their utterances and/or carried a lesser degree of sentence stress.

There were 20 instances in which /t/ appeared in short quantity. The average duration of these occurrences was 4.7 csec, the range from 2 to 8 csec, with a median of 5 csec, and 12 out of the 20 occurrences between 4 and 5 csec. The shortest occurrence of syllable-final /t/ (2 csec) was in teadlane (497), in which /t/ followed a diphthong in quantity 3.

Examples of syllable-final /t/ are given on Figure 2, which contains the word katki (133), in which the duration of syllable-final /t/ was 18 csec. This figure also presents the word jatkake (147), in which the same /t/ + /k/ cluster occurred with /t/ in short quantity and a duration of 4 csec. Figure 7 contains the word leidsid (496), in which the first /t/ had the duration of 3 csec.

5. Allophones of /k/

5.1. Intervocalic /k/

5.1.1. Intervocalic /k/ in quantity 1

The 500 sentences analyzed during this study contained 55 instances in which intervocalic /k/ occurred in quantity 1 between the first and the second syllable of a word. The average duration of these occurrences was 3.6 csec. The durations ranged from 2 to 6 csec, with a median value of 3.5 csec, and 33 out of 55 occurrences falling between 3 and 4 csec. A rather great percentage (15 instances) of occurrences of /k/ in quantity 1 were realized as voiced fricatives; these productions had an average duration of 2.8 csec. Out of seven values of 5 and 6 csec, six

occurred in words that were last in their respective utterances. There were also several values of 2 and 3 csec in words that were last in the utterance, and the distribution of the shortest values appeared not to follow any particular pattern.

Allophones of /k/ in quantity 1 occurred also in 16 words between the second and third syllable. The average duration of these 16 occurrences was 3.8 csec; the range was from 2 to 6 csec, with 12 out of 16 occurrences between 3 and 4 csec. These 16 manifestations included three occurrences of a voiced fricative allophone of /k/; the average duration of these three was 2.7 csec. The longest occurrences — three values of 5 and 6 csec — were again found in utterance-final words.

In five instances, /k/ in quantity 1 occurred between the third and fourth syllable; the average duration was 3.3 csec, ranging from 2 to 4 csec. In one case each, /k/ in quantity 1 occurred between the fourth and fifth syllable and between the fifth and sixth syllable; the duration of the former was 3 csec, that of the latter 4 csec.

Examples of intervocalic /k/ in quantity 1 are shown on two figures. Figure 1 contains the word taga (30), the last word of this utterance, in which /k/ in quantity 1 has the duration of 6 csec. In the word mattidega (36), shown on the same figure, /k/ had the duration of 4 csec. Figure 6 contains two further examples. The word mahlaga (458) was pronounced with a 4 csec long /k/ allophone. The word keegi (485) was unstressed in its utterance; in this word intervocalic /k/ in quantity 1 appeared as a voiced fricative with a duration of 3.5 csec.

5.1.2. Intervocalic /k/ in quantity 2

The sentences contained ten occurrences of /k/ in quantity 2 between the first and the second syllable. The average duration of /k/ in these utterances was 7.4 csec. The durations ranged from 4 to 10 csec, with a median of 7.5 csec, and seven out of ten occurrences falling between 7 and 9 csec. There was one instance (the word pakid [143]) in which the intervocalic /k/ in quantity 2 contained a spike in the center of the plosive gap, suggesting that rearticulation of /k/ had taken place.

The materials also contained two occurrences of /k/ between the second and third syllable, following a first syllable in quantity 3, in which /k/ was subjectively judged to be in phonemic quantity 2. The durations of /k/ in these instances were 7 csec in the word puusliku (495) and 8 csec in the word luustiku (496). Both words are offered as examples on Figure 7. An instance of /k/ in quantity 2 between the first and second syllable is given on Figure 4, which contains the word pikad (296). The duration of /k/ in this word was 7 csec.

5.1.3. Intervocalic /k/ in quantity 3

Intervocalic /k/ occurred between the first and second syllable in 21 instances in quantity 3. In 16 of these occurrences, the vowel preceding /k/ was short; the average duration of /k/ was 17.9 csec. The range of durations was considerable: the shortest occurrences were 10 csec long (measured in two productions of kukkus, utterances 51 and 462), the longest realization had a duration of 30 csec (in the word sukka, occurring in final position in sentence 125). The median value was 15 csec, and there was a concentration of occurrences in that duration region, six of the 16 productions having values between 13 and 15 csec. In general, the longest values were again found in disyllabic words in final position within the utterance.

The five instances of /k/ in quantity 3 following a vowel or diphthong in quantity 3 had an average duration of 13.4 csec and a range from 10 to 17 csec.[15]

In five cases there appeared a spike on the spectrograms within the gap corresponding to /k/ in quantity 3.

There were two words in which intervocalic /k/ occurred between the second and third syllable in what was subjectively judged to be quantity 3. These words were puuslikku (493), in which /k/ had the duration of 20 csec, and luustikku (497), with a /k/ duration of 18 csec. In both cases, there was also a spike within the gap corresponding to the /k/ in quantity 3. These durations may be compared with the durations of /k/ in puusliku (495) and luustiku (496), which were 7 and 8 csec respectively (cf. above). In this position, a phonemic opposition between /k/ in quantity 2 and 3 is obviously present.

Figure 4 contains two occurrences of /k/ in quantity 3. The word rukki (287) had a /k/ with a duration of 14 csec. The word kukkuda (390) contained /k/ with a duration of 28 csec. Figure 5 presents kokku (439), with a /k/ duration of 14 csec. Figure 6 contains the word kooki (458), in which the intervocalic /k/, following a vowel in quantity 3, had a duration of 12 csec and a spike at 6 csec, and the word puuslikku (493), with a /k/ duration of 20 csec and a spike within the gap at 12 csec. Figure 7 offers the word luustikku (497), with a /k/ duration of 18 csec and a suggestion of a spike within the gap.

5.1.4. Intervocalic /k/ of ambiguous duration

There were 14 instances in which an intervocalic long /k/ occurred between the second and third syllable in words whose first syllables were in quantity 1 or 2. The average duration of these occurrences was 12.7 csec. The durations ranged from 7 to 18 csec, with a median between 12 and 14 csec and very diffuse distribution: only the extreme value 18 csec occurred three times,

all the other values appearing only once or twice. The longest durations were measured in words which were final in their respective utterances; the shortest manifestation (7 csec) occurred in the word viisakusetust (74), which was the longest word of the group. There was one instance (jatkake [147]) in which /k/ contained a spike.

Four examples of /k/ in this duration are presented. Figure 1 contains the word kõidikud (116), with an intervocalic /k/ lasting for 9 csec. Figure 2 contains jatkake (147), in which intervocalic /k/ had a duration of 11 csec and a spike at 4 csec. The word lühike (287), with a /k/ duration of 18 csec, is given on Figure 4, and the word nuustiku (494), with a /k/ duration of 14 csec, is offered on Figure 6.

5.2. Initial /k/

5.2.1. Utterance-initial /k/

Out of the 500 utterances 81 began with /k/. The duration of utterance-initial /k/ could be measured in 40 instances; the average duration of /k/ in these utterances was 8.8 csec. In 41 instances, the duration of initial /k/ could not be measured.

The figures contain several examples in which breath noise preceded the presumable onset of utterance-initial /k/. Two might be pointed out: the utterance beginning with kaks (275), Figure 3, in which the duration of initial /k/ was approximately 8 csec, and the utterance beginning with koli (401), Figure 5, in which the breath noise ceased for approximately 14 csec.

5.2.2. Word-initial /k/ following a word ending in a vowel

There were 113 sequences in which a word ending in a vowel was followed by a word beginning with /k/. In 107 instances the word beginning with /k/ had some degree of sentence stress; in six instances, the word was subjectively unstressed. The average duration of the 107 stressed occurrences was 5.3 csec. The range of these 107 occurrences was from 3 to 10 csec, with 79 occurrences falling between 4 and 6 csec, and a median of 5 csec. The shortest occurrences obviously represent a relatively reduced degree of sentence stress; if a more rigorous criterion for determining the degree of sentence stress were available, it is quite probable that the shortest occurrences would fall in a category with minimum stress. There were also four instances in which initial /k/ appeared as a voiced fricative; the durations of these manifestations were 3, 3, 4, and 6 csec, the longest fricative-type allophone occurring at the beginning of the word kata in the sequence ära seda kinni kata (383), where kinni carried

primary sentence stress. The longest occurrence, 10 csec, was found in the sequence on ju kuulus (23), in which kuulus had a relatively high degree of stress.

The six occurrences classified as unstressed had an average duration of 3.3 csec. Three out of the six consisted of a sequence of a word ending in a vowel followed by the unstressed particle kui. The durations ranged from 2 to 4 csec; the shortest occurrence was also voiced and had a fricative quality.

Illustrations of initial /k/ after a word ending in a vowel are included on several figures. Figure 2 contains the sequence taktikepp (163), in which /k/ began the second component of a compound, and had a duration of 4.5 csec. The figure contains further the sequence Narva kosk (171), with a /k/ duration of 6 csec. Figure 4 contains the sequence rukki kõrs (287), pronounced not as a compound but as a sequence of two separately stressed words; the duration of /k/ here was 3 csec. On the same figure, the word teekäija (390), a compound word, had a /k/ duration of 6 csec. Figure 5 contains the sequence uude korterisse (401), in which korterisse probably had the highest degree of sentence stress; the duration of initial /k/, however, was 3 csec. Figure 6 contains the sequence niisuta kooki (458), with a /k/ duration of 4.5 csec, and seda keegi (485), with a /k/ duration of 4 csec.

5.2.3. Word-initial /k/ following a word ending in a consonant

All 108 occurrences of allophones of /k/ in this position appeared in words that seemed to have at least a minimum amount of stress to keep them from being classified as unstressed. The average duration of /k/ in these instances was 6.1 csec. The range was considerable; some segmental conditioning factors could be discovered which seemed to exert considerable influence on the duration of the initial /k/. The shortest measured value was 2 csec, the longest 10 csec. Out of the six occurrences of values between 2 and 3 csec, five were found in sequences of nasal + /k/, and one in the sequence /l/ + /k/. The median value was 6 csec, and 67 out of 107 durations clustered between 6 and 8 csec. The longest occurrences of initial /k/ appeared connected with words carrying a relatively great degree of sentence stress.

The sentences also contained six instances in which a final /k/ was followed by a word beginning with /k/. In the sequences loog kokku (439), saag kasti (440), saak kasti (441), and saag koju (442) the duration of the individual components was not measurable; the total durations were 20 csec for the first two and 22 csec for the last two sequences. However, in the sequence saak

koju (443), the gap representing the voiceless plosive contained a clearly defined release at 18 csec, followed by a further gap of 4 csec, for a total of 22 csec. The spike appearing in this /k/ + /k/ sequence was similar to those observed in intervocalic /k/ in quantity 3. In a sixth such sequence, pakk koju (445), the total duration of the /k/ + /k/ sequence was 28 csec, and the individual components could not be separated.

Illustrations of sequences consisting of a word-final consonant followed by a word-initial /k/ are offered on Figures 1-6. Figure 1 contains the sequence on kapi (30), with /k/ duration 6 csec. Figure 2 contains the sequences on katki (133), with /k/ duration 3 csec, and taktikepp käes (163), with /k/ duration 7 csec. Figure 3 contains the sequence on keset koske (172), where the first /k/ had the duration of 5.5 csec, the second /k/ - 8 csec, and the sequence on karbis (275), with /k/ duration 2 csec. Figure 4 contains the sequence hüppas, kirp (276), in which the utterance contained a syntactic break before /k/; the duration of /k/ was 4 csec. In ähvardas kukkuda (390) on the same figure, the duration of /k/ was 6 csec. Figure 5 contains the sequence loog kokku (439), where the /k/ + /k/ sequence had a duration of 20 csec, and the sequence saak koju (443), in which the plosive gap contained an indication of the release of the first plosive before the onset of the second plosive, with a spike at 18 csec. The total duration of the gap was 22 csec. Figure 6 contains küll kohtunik (454), with /k/ duration 6 csec, and nad kummardasid (493), with /k/ duration 7 csec.

5.2.4. Syllable-initial /k/ as second member of an intervocalic cluster

The materials contained 59 instances in which /k/ occurred as second member of an intervocalic consonant cluster in quantity 1, and 5 instances in which /k/ appeared in that position in quantity 3. The average duration of the 59 occurrences in quantity 1 was 4.2 csec. The range was from 2 to 10 csec, with a median at 4 csec, and 29 out of 49 durations between 4 and 5 csec.

There were twelve instances in which the duration of /k/ was only 2 csec; ten of these instances consisted of sequences /n/ + /k/, while the clusters /r/ + /k/ and /l/ + /k/ accounted for one occurrence each. The longest occurrences were associated with words that were final in their respective utterances: katku (146), with 10 csec, katki (133), with 8 csec, koske (172), with 8 csec, and õhku (306), with 8 csec. In four instances, the allophone of /k/ was manifested as a fricative.

The five occurrences in which /k/ was in quantity 3 had an average duration of 21.4 csec. The range was from 16 to 27 csec.

The shortest occurrence took place in silku (243), with 16 csec; the longest realization (27 csec) occurred in nurka (265), which was also the last word in the utterance.

Illustrations of allophones of /k/ as second member of an intervocalic cluster include the following. Figure 2 contains utterance 133 with the words kinga and katki, in which syllable-initial /k/ had the durations of 2 and 8 csec respectively. On the same figure, the word jatkake (147) had a syllable-initial /k/ with the duration of 3.5 csec. On Figure 3, the word koske (172) contained a syllable-initial /k/ with a duration of 8 csec; the word pange (248) had a /k/ lasting 2 csec. On Figure 4, the word kargas (276) contained a syllable-initial /k/ of 4 csec duration; on Figure 5, the word pange (404) had again a /k/ with a duration of no more than 2 csec.

5.3. Final /k/

5.3.1. Utterance-final /k/

Only a relatively small number of utterances contained an utterance-final /k/. Of these, three were unambiguously assignable to quantity 3. Their durations were 20, 28, and 45 csec, with an average duration of 31.0 csec. These three examples affirm again that a final plosive in quantity 3 is longer when it follows a short vowel than when it follows a long vowel or diphthong: the duration of /k/ in the words pikk (300) and plekk (335) was 28 and 45 csec respectively, while the word maik (197) had a /k/ lasting for 20 csec.

There were four instances in which utterance-final /k/ was ambiguously long, i.e. occurred in final position in words of a type in which no contrast between final consonants in quantity 2 and quantity 3 is normally observed. The average duration of these four occurrences was 13.8 csec; the values ranged from 12 to 16 csec. A slight correlation between the number of syllables and the duration of final /k/ could be observed: the two disyllabic words in the group, osmik (174) and metsik (202), had /k/ durations of 12 and 13 csec, while the trisyllabic words imelik (402) and elanik (417) had values of 14 and 16 csec respectively.

An example of utterance-final /k/ is offered on Figure 4, which contains the word pikk (300), with /k/ duration 28 csec.

5.3.2. Word-final /k/ followed by a word beginning with a vowel

There were five sequences in the test materials in which a word ending in /k/ was followed by a word beginning with a vowel. Two of the instances were monosyllabic words followed by the unstressed verb form oli; their durations were 24 csec for kukk

oli (17) and 16 csec for puutikk oli (500). The latter sequence contained a spike during the /k/ gap at 11 csec. The three other instances of word-final /k/ were ambiguous with respect to quantity: clearly not quantity 1, but indeterminate as to whether it was quantity 2 or 3. The durations of these occurrences were 4.5, 6.5, and 7 csec, with an average of 6 csec. One of the three (luustik oli, [498]) contained a spike in the middle of the gap.

Examples are given on Figure 6, which contains the sequence kohtunik annab (454), with /k/ duration 4.5 csec. Figure 7 contains the sequences luustik oli (498), with /k/ duration 6.5 csec and a spike at 3.5 csec, and puutikk oli (500), in which /k/ duration was 16 csec and a spike occurred at 11 csec.

5.3.3. Word-final /k/ followed by a word beginning with a consonant

The number of such sequences was exceedingly small. If the six instances of /k/ + /k/ are excluded (cf. the discussion above, under word-initial /k/), there were only two instances. The sequence kõik pole (225) contained a /k/ in a subjectively overlong quantity; however, in the realization of the sentence, the duration of /k/ was only 4 csec. In the other sequence, kassipoeg püüab (50), final /k/ in quantity 1 had a duration of 6 csec. This utterance is also included as an illustration on Figure 1.

5.3.4. Syllable-final /k/ as first member of an intervocalic cluster

There were 16 instances in which a cluster of two, with /k/ as first member, occurred in intervocalic position. In twelve instances, /k/ occurred in short quantity; the average duration of these occurrences was 4.0 osec. The median value was 4 csec, the range from 2 to 6 csec, and seven out of the twelve instances had durations between 4 and 5 csec. The longest value (6 csec) occurred in the word liigne (341), in which, however, the voiceless /k/ had a slightly fricative quality. The shortest values occurred in maksa (217), maksab (459), and maksa (460), in which the allophones of /k/ had a fricative quality and the respective durations of 2, 2.5, and 3 csec.

The four occurrences of overlong /k/ in syllable-final position had an average duration of 10.9 csec. The average is not very meaningful, however, since the range was from 4.5 csec to 16 csec. The extremely short value occurred in peaksime (477); the longest value occurred in kaklevad (123).

Figure 2 contains a spectrogram of utterance 163 with the word taktikepp (163), in which syllable-final short /k/ had the duration of 4.5 csec.

6. Allophones of /s/ and /s'/

For reasons analogous to those discussed in connection with /t/ and /t'/, the allophones of /s/ and /s'/ are combined in this presentation, and the symbol /s/ is used to refer to both phonemes.

6.1. Intervocalic /s/

6.1.1. Intervocalic /s/ in quantity 1

There were 53 instances in which /s/ occurred in quantity 1 between the first and the second syllable. The average duration of these occurrences was 8.9 csec, the median value 9 csec. The range was from 6 to 14 csec; the distribution of the values between 6 and 12 csec was rather even, and 33 out of 53 occurrences had durations between 7 and 10 csec. All, even the shortest productions of intervocalic /s/ in quantity 1, were completely voiceless.

There were 30 instances in which /s/ in quantity 1 occurred between the second and the third syllable. The average duration of these 30 occurrences was 8.5 csec. The range was from 6 to 12 csec, the median value 8 csec; 24 out of 30 occurrences had durations between 7 and 10 csec. The three occurrences in which the duration of /s/ in quantity 1 was 12 csec were in words in final position within the utterance.

The materials contained also 13 occurrences of /s/ in quantity 1 between the third and fourth syllable. The average duration of these occurrences was 7.9 csec, the range from 6 to 12 csec; the median value was 7 csec, and ten out of 13 occurrences had values between 6 and 8 csec. There were further three occurrences of /s/ in quantity 1 between the fourth and the fifth syllable; the values were 7 csec in ettevaatamatuse (65), 10 csec in kõnelemisi (67), and 10 csec in ootamatusega (75). It is obvious that allophones in quantity 1 are not affected in any significant manner by the length of the word in which they appear.

Illustrations of /s/ in quantity 1 are offered on Figures 2-6. Figure 2 contains the word väsinud (149), with /s/ duration 11 csec. Figure 3 shows the word keset (172), with /s/ duration 7 csec. Figure 5 contains the words lase isa (395), with /s/ durations 8 and 6 csec. Figure 6 includes the word niisuta (458), with /s/duration 7 csec, and the word kummardasid (493), in which /s/ also had a duration of 7 csec.

6.1.2. Intervocalic /s/ in quantity 2

The materials contained only two instances of intervocalic /s/ in quantity 2. The durations of these two occurrences were 12 csec in kassapidaja (49) and 14 csec in kassipoeg (50). The latter word is reproduced on Figure 1.

6.1.3. Intervocalic /s/ in quantity 3

Only four instances of intervocalic /s/ in quantity 3 were included in the sentences, one of which occurred between the third and fourth syllables. The durations of the three instances of /s/ in quantity 3 between the first and the second syllable were 27, 28, and 30 csec. The duration of /s/ in the word korterisse (401) was 23 csec. This word is reproduced on Figure 5. The same figure contains also the word sisse (395), where /s/ had the duration of 30 csec.

6.1.4. Intervocalic /s/ of ambiguous duration

Since the illative case suffix in Estonian is -sse, the sound may be expected to occur between the next but last and the last syllable in words of all types. The test material did not contain examples of intervocalic /s/ in long quantity between the second and third syllable. Therefore it is not possible at the moment to state the differences, if any, in the duration of /s/ in words such as talusse, kindlasse, and elamusse. Subjectively the situation appears to be analogous to that described in connection with the plosives; /s/ may be assigned to quantity 3 in such words as kindlasse and elamusse, but the duration of /s/ in such words as talusse appears ambiguous. The question was not anticipated when the sentences were constructed, and no words of this type were included in the set of 500 utterances. A firm statement about the duration of /s/ in this ambiguous position therefore cannot be made until additional data are analyzed containing such occurrences.

6.2. Initial /s/

6.2.1. Utterance-initial /s/

The duration of the voiceless fricative /s/ can be measured in initial position much more easily than the duration of initial plosives. This provides a welcome opportunity to compare the durations of a considerable number of utterance-initial allophones of /s/ with the durations of intervocalic and word-initial allophones. In the 70 instances in which utterance-initial /s/ appeared, its average duration was 10.4 csec. The values ranged from 8 to 16 csec; the median value was 10 csec, and 48 out of 70 occurrences had durations between 9 and 12 csec. The longest occurrences were associated with words carrying a relatively great degree of sentence stress. There were a considerable number of instances in which the sentence started with the unstressed demonstrative pronoun see; however, none of the productions was shorter than 8 csec.

Three instances of see in utterance-initial position are included on the illustrations. On Figure 3, /s/ in see (264) was 12 csec long. In utterances 498 and 500, shown on Figure 7, the durations of /s/ in see were 8 and 9 csec respectively.

6.2.2. Word-initial /s/ following a word ending in a vowel

Of the 65 occurrences of such sequences, the word beginning with /s/ was stressed in 40 cases and unstressed in 25 cases. The average duration of the stressed allophones was 10.8 csec. The range of these occurrences was from 8 to 16 csec, with a median value of 11 csec and 26 out of 40 durations between 10 and 12 csec.

The average duration of the 25 occurrences of /s/ at the beginning of unstressed words was 7.7 csec. In most of these instances, the word beginning with /s/ was an unstressed form of the demonstrative pronoun see or a short form of the personal pronoun sa. The range of these occurrences was from 5 to 11 csec; the median value was 8 csec, and 19 out of 25 instances had durations between 6 and 9 csec. The two words with /s/ durations of 10 and 11 csec probably had a relatively greater degree of sentence stress than the others.

Illustrations of word-initial /s/ following a word ending in a vowel are offered on several of the figures. The sequence kata see (36), with /s/ duration of 9 csec, appears on Figure 1. Figure 3 contains the sequence pange süldile sinepit (248), with /s/ durations of 10 and 11 csec respectively. Figure 5 contains isa sisse (395), with 8 csec for initial /s/, and too saak (443), with 11 csec for /s/. Figure 7 contains the sequence puusliku silmad (495), with /s/ duration of 9 csec.

6.2.3. Word-initial /s/ following a word ending in a consonant

There were 35 instances in which a word beginning with /s/ followed a word ending in a consonant different from /s/. In addition, there were 28 instances in which the consonant sequences consisted of /s/ + /s/. In the first group there were 28 instances in which the word beginning with /s/ had a noticeable degree of sentence stress. In these instances, the average duration of /s/ was 11.5 csec; the range of durations was from 8 to 17 csec, with a median of 12 csec and 19 out of 28 instances between 10 and 13 csec.

The seven unstressed instances had an average duration of 8.3 csec; three of the seven occurrences had a duration of 8 csec, and the range was from 6 to 11 csec.

Since in the case of plosives a preceding nasal had a shortening influence on the plosives starting the next word, it may be of interest to state separately the average duration of occurrences of /s/ in the sequence /n/ + /s/. In 15 such occurrences the average duration of /s/ was 10.4 csec; in ten sequences of /t/ + /s/, the average duration of /s/ was 10.9 csec. It appears thus that a preceding nasal has no influence on the duration of the allophone of /s/ beginning the next word.

In sequences of /s/ + /s/, there were ten stressed instances (such as kuidas sült [249]), and 18 unstressed sequences (such as mis sa [8]). The average duration of the /s/ + /s/ sequences in the stressed instances was 19.4 csec, in the unstressed instances 9.5 csec.

Figure 6 contains the sequence peab seda (485), where unstressed initial /s/ had the duration of 11 csec.

6.2.4. Syllable-initial /s/ as second member of an intervocalic cluster

There were 44 instances in which a cluster with /s/ as second member occurred between the first and the second syllable. In 42 of these instances, /s/ appeared in quantity 1. The average duration of /s/ in these manifestations was 9.0 csec. The range was from 6 to 16 csec; the median value was 8 csec, and 28 out of 42 instances fell between 7 and 10 csec. The longest occurrences were found in the words rukkikõrsi (288) and põrsa (285), with /s/ durations of 14 and 16 csec. In this /r/ + /s/ cluster, the speaker tends to substitute /r/ in quantity 1 + /s/ in quantity 3 for the cluster /r/ in quantity 3 + /s/ in quantity 1, and although an attempt was made to produce the required duration ratio, evidently the results were still somewhat on the ambiguous side. However, one of the 14 csec long manifestations of /s/ also occurred in the cluster /p/ + /s/ in the word kepsu (145).

In the two instances in which /s/ appeared in quantity 3 and contained the syllable boundary, the values were 24 csec (in kärssa [284]) and 26 csec (in pulssi [261]).

Two illustrations of clusters with /s/ as second member are offered on the figures. Figure 2 contains the word lapsed (149), with /s/ duration 9 csec; Figure 7 contains the word leidsid (496), in which /s/ had a duration of 7 csec.

6.3. Final /s/

6.3.1. Utterance-final /s/

In 53 instances /s/ occurred in final position in quantity 1. The average duration of allophones of /s/ in this position was 13.7 csec. The durations ranged from 10 to 19 csec; the median

value was 13 csec, and 36 out of 53 occurrences fell between 12 and 14 csec. No regularities could be observed that would have been associated with either the longest or the shortest occurrences.

Examples of utterance-final /s/ are given on Figure 2, containing the word käes (163), in which /s/ had the duration of 13 csec, and võimas (171), with a final /s/ lasting 15 csec. Figure 3 contains karbis (275), where /s/ was 12 csec long; Figure 4 presents the word kargas (276), in which utterance-final /s/ had a duration of 13 csec.

6.3.2. Word-final /s/ followed by a word beginning with a vowel

The material contained 13 instances of this type. The average duration of /s/ in this position was 9.9 csec; all occurrences were in quantity 1. In eight of the 13 instances, the word following the word ending in /s/ was the unstressed verb form on. The range of the durations was from 7 to 11 csec; nine out of the 13 occurrences fell between 8 and 10 csec. In this small sample there appeared no difference between stressed and unstressed words.

Figure 2 contains the sequence pealis on (133), in which /s/ had the duration of 8 csec.

6.3.3. Word-final /s/ followed by a word beginning with a consonant

There were 62 instances in which /s/ occurred in quantity 1 in word-final position, followed by a word beginning with a consonant. The average duration of these occurrences was 8.2 csec. The range was from 4 to 15 csec; the median value was 8 csec, and 45 out of 62 occurrences fell between 6 and 10 csec.

In a considerable number of instances, the sequence /s/ + consonant occurred at the boundary of two unstressed monosyllabic words such as kas ma, mis ta, kus ta etc. In 16 unstressed occurrences of this kind, the average duration of /s/ was 5.3 csec. These occurrences also account for the instances in which the duration of /s/ was below the median. The extremely long durations, on the other hand, were associated with words carrying a considerable degree of sentence stress.

There were four instances in which /s/ occurred in quantity 3 in word-final position, followed by a word beginning with a consonant. The average duration of these four occurrences of /s/ was 11.8 csec; the range was from 9 to 15 csec. The two values of 9 csec occurred in the sequences poiss näitas (227) and poiss nägi (295); in both instances, /s/ in quantity 3 was preceded by a diphthong in quantity 3. Two occurrences of the word kass, with

/s/ in quantity 3 following a vowel in quantity 1, had values of 14 csec. These were found in kass käunub (95) and kass käunus (96).

Examples of word-final /s/ followed by a word beginning with a consonant may be seen on several of the illustrations. Figure 4 contains the sequences hüppas, kirp (276), with /s/ duration 9 csec, and ähvardas kukkuda (390), with /s/ duration 11 csec. Figure 5 contains the sequence uus paber (404), with /s/ duration 10 csec; Figure 7 offers the sequence uuris tundmatut (497), in which word-final /s/ had a duration of 9 csec.

6.3.4. Syllable-final /s/ as first member of an intervocalic cluster

There were 22 instances in which syllable-final /s/ appeared in a cluster of two in short quantity between the first and the second syllable. The average duration of these occurrences was 8.9 csec; the range was from 5 to 21 csec, with a median value of 8 csec and 15 out of 22 durations falling between the values 6 and 11 csec. The shortest durations were associated with words in which the vowel of the first syllable was either in quantity 1 or 2; the longest values occurred in words in which the vowel or diphthong of the first syllable was in quantity 3. The isolated value of 21 csec occurred in the word niiske (366), where /i/ was in quantity 3 and the word was final within its utterance. The next longest duration was 13 csec in the word laiskuse (170), in which /s/ likewise followed a diphthong in quantity 3.

There were 12 instances in which an /s/ + consonant cluster, with /s/ in quantity 1, occurred between the second and the third syllable of a word. In all such instances, the vowel of the first syllable was either in quantity 1 or in quantity 2. The average duration of /s/ in these occurrences was 8.0 csec; the range was from 4 to 14 csec, with a median value of 8 csec and seven out of 12 occurrences having durations between 6 and 9 csec. The longest value, 14 csec, occurred in the word uuristaja (365), where the word was in final position. The shortest values occurred in relatively unstressed words, although the distinction between the degrees of stress was rather difficult to make. The value of 4 csec occurred in the word armastan (306), which was first in an utterance consisting of three words.

There were 17 instances in which /s/ occurred in overlong quantity in syllable-final position in a cluster between the first and second syllable. The average duration of these occurrences was 13.3 csec. The range of durations was quite extensive, reaching from 6 csec to 23 csec. There was no appreciable concentration of durations around any one value; the distribution

was rather smooth over the whole range. The median value was 13 csec. The longest occurrences were associated with final position in the sentence, /s/ in overlong quantity occurring after a short vowel. The extreme value of 23 csec occurred in the word kaske (180), which was final in the utterance.

In three instances /s/ occurred in overlong quantity at the boundary of the third and fourth syllable. The words and the durations of /s/ were, respectively, haledasti (95), 12 csec, haledasti (96), 14 csec, and tugevasti (232), 16 csec. The materials contained a comparable word with /s/ in short quantity, kangelaste (71), in which the duration of /s/ was 8 csec. The average value of 14 csec for the first three words and the value of 8 csec for the fourth fall very close to the average values established for the two contrastive durations of /s/ in clusters between the first and second syllable.

Illustrations of /s/ in syllable-final position between the first and second syllable are offered on several figures. Figure 3 contains the word koske (172), with /s/ duration of 20 csec. In Figure 6, the words puuslikku (493) and nuustiku (494) had /s/ durations of 11 csec and 9 csec respectively. Figure 7 contains puusliku (495), luustiku (496), luustikku (497), and luustik (498), with /s/ durations of 7 csec, 12.5 csec, 11 csec, and 10 csec respectively.

7. The function of consonant quantity in establishing phonological units in Estonian

7.1. Intervocalic quantity

Once the characteristic durations of consonants in the three phonemic quantities have been established in intervocalic position, it is possible to determine whether occurrences of consonants in word-initial and word-final position resemble intervocalic occurrences with regard to quantity, or differ from them in a consistent manner. If the durations of initial and final consonants fall close to the average values established for consonants in intervocalic position, it is likely that the word has become part of a higher-level phonological unit.[16] Differences between the durations of consonants in word-initial and word-final position on the one hand, and intervocalic consonants on the other hand, serve as signals to the presence of a word boundary.

In the course of the investigation reported on the preceding pages, a number of the characteristics of consonants in the various quantities were established. Although the report has concentrated on measured quantities, it should be kept in mind that the patterns depend on relationships at least as much as on the

actual durations of individual manifestations. This becomes obvious when the characteristic durations of the various positional allophones associated with the different consonants are compared among themselves. The fact that absolute values alone do not determine phonemic quantities is immediately evident from the observation that allophones of /p/ were generally longer than comparable allophones of /t/ and /k/, while the allophones of /s/ were often twice as long as the comparable allophones of the plosives. Quantitative as well as qualitative differences were especially great in intervocalic quantity 1, where allophones of /t/ and /k/ were often voiced or fricated; allophones of /p/ were never fricated, and neither allophones of /p/ nor allophones of /s/ were ever voiced in this position.

The observed allophonic variation within each quantity is another factor that underscores the relative nature of the durational patterns. The conditioning factors discovered during the investigation include degree of sentence stress, position within the utterance, number of syllables within the word, syllable structure, and segmental environment. Some of these factors appeared to have greater influence on consonants in quantity 3 than on the two shorter quantities.

Intervocalic consonants in quantity 1 were, as a rule, unaffected by their position within the word: occurrences at the boundary of the first and the second syllable did not differ significantly from occurrences at the boundary of syllables farther removed from the beginning of the word. The question of the manifestation of phonemic quantities 2 and 3 in positions other than the boundary between the first and second syllable is a complicated one; some observations have been reported earlier in this paper, and a brief summary will be offered after the general characteristics of consonants in quantity 2 and quantity 3 at the boundary between the first and second syllable have been reviewed.

Intervocalic consonants in quantity 2 were approximately twice as long as consonants in quantity 1; /t/ and /k/ showed occasional spikes within the gap corresponding to the rearticulated short geminate. These consonants were also characterized by a relatively narrow range of durations and correspondingly small amount of allophonic variation.

Several observations were made in connection with intervocalic quantity 3. In general, intervocalic consonants in quantity 3 had the widest range of allophonic variation. According to general practice, the overlong consonants terminating an overlong syllable were included in quantity 3, regardless of the length of the preceding vowel. It was found, however, that when

the vowel was in quantity 1, the average duration of the consonant in quantity 3 was more than twice as long as the average duration of the consonant in quantity 2; when the vowel or diphthong was in quantity 3, the duration of the consonant in quantity 3 was not much greater than the average for quantity 2, and the extremes of the two ranges overlapped. If the consonants terminating an overlong syllable are uniformly assigned to quantity 3, the allophonic realization of the consonant quantity appears very strongly conditioned by the quantity of the preceding vowel.

This observation emphasizes again that it is the interaction of vowel and consonant quantity, together with the placement of the syllable boundary, which determines the syllabic quantity. The presence of one vowel or consonant in quantity 3 is necessary and sufficient to establish the overlong quantity of a syllable. If the vowel is in quantity 1, the consonant in quantity 3 carries the whole burden in determining the syllabic quantity. If the vowel or diphthong is in quantity 3, the quantity of the consonant terminating the syllable is redundant as far as manifesting the syllabic quantity is concerned, but the quantity of the consonant remains contrastive on a segmental level. Under these circumstances, however, only a two-way contrast is possible; after a vowel in quantity 3, a consonant may occur either in quantity 1 or in a non-contrastively long quantity.[17] The problem of the phonemic quantity of the consonant in sequences treated up to now as consisting of segments in quantities 3 + 3 will be considered in more detail after the paragraph dealing with consonants in ambiguous quantity between the second and the third syllable.

An attempt has been made in this paper to explore the positions beyond the boundary of the first and second syllable at which contrasts between consonants in the different quantities may occur. The rhythmic structure of the words is determined by the number of syllables, their quantity, and the placement of secondary stress. Contrasts between all three phonemic quantities of consonants were found to occur in the first syllable of words with two or more syllables, and in the third syllable of words with four or more syllables. (The material did not contain enough examples of longer words to make it possible to extend the statement to successive odd-numbered syllables.) When the contrasts occurred between the third and the fourth syllable, the structure of the two preceding syllables was irrelevant. Contrasts between all three quantities were also found between the second and the third syllables of words of three or more syllables, when the first syllable was in syllabic quantity 3. In words with three or more syllables, whose first syllable was in either quantity 1 or quantity 2, only two consonant quantities occurred between the

second and the third syllable. One of these quantities was short, and allophones of consonants in this quantity were in every respect similar to allophones in quantity 1 in intervocalic position between the first and the second syllable. The other duration appeared ambiguous; no contrast between consonants in quantity 2 and quantity 3 was found in such words, and the decision concerning the assignment of such long consonants to a phonemic quantity has been postponed up to now.

A study of the measured durations of plosives in quantity 2, quantity 3, and this ambiguous quantity reveals that the durations of consonants in the ambiguous quantity are most similar to the durations of plosives in quantity 3 following vowels or diphthongs in quantity 3. As was suggested above, the duration of consonants in this position is likewise ambiguously long. A comparison of words containing plosives in ambiguous quantity between the second and the third syllable with words whose first syllables contain a vowel in quantity 3, followed by a consonant in ambiguously long quantity, suggests that at the level of word patterns, the two short syllables of such words as koguta (387) or huvitav (498) are rhythmically equivalent to the overlong first syllables of such words as saata (382) and kooki (458). The actual manifestations of the plosives in words with these two patterns are not only similar with regard to average duration, but also in respect of range, scattering of values, and the occasional presence of spikes indicating rearticulation.[18]

It is an interesting fact that first syllables in quantity 1 and quantity 2 appear equivalent in providing the environment in which the plosives may occur in the so-called ambiguous quantity.[19]

Within a word-level unit, consonants in the quantity up to now called ambiguous are thus equivalent to what up to now have been considered certain positionally conditioned allophones of consonants in quantity 3. The subjective feeling of ambiguity in words like huvitav is due to lack of contrast between consonant quantities 2 and 3. Words such as saata are perceptually unambiguous: the first syllable in such words is in syllabic quantity 3. As far as the segmental quantity of the intervocalic consonant is concerned, however, the ambiguity is present in both cases: there is no contrast between quantity 2 and quantity 3 in either word type. Since the consonants in these two positions are similar in phonetic properties (especially duration) and in their status with regard to phonological oppositions in which they participate, it appears that they should be assigned to the same phonological quantity. The two quantities that come under consideration are quantity 2 and quantity 3.

Phonetically, the consonant occurring in both word types is longer than an intervocalic consonant in quantity 2 and shorter than an intervocalic consonant in quantity 3 after a vowel in quantity 1. Since the greatest number of examples was available for /t/, the specific instances of durations of allophones of /t/ might be reviewed here. The duration of /t/ in intervocalic quantities 1 and 2 was 3.0 and 8.3 csec respectively. After a short vowel, intervocalic overlong /t/ had the average duration of 21.1 csec; after an overlong vowel (i. e. in final position in a closed overlong first syllable), the average duration of allophones of /t/ was 12.4 csec. The duration of /t/ in ambiguous quantity between the second and the third syllable was 12.1 csec. The data thus prevent us from identifying either of the two intermediate quantities with either of the phonemic quantities unless some other considerations are brought in that may be used to identify the conditioning factors which determine the selection of the particular durational allophone.

Let us consider first the consequences of assigning both allophones to quantity 3. This is the traditional position with regard to the consonant in such words as saata, so no reinterpretation is necessary for the quantity of this allophone. However, the assignment of the consonant in huvitav to the same quantity as that of saata, namely quantity 3, would have serious theoretical consequences. The 'overlength' of vowels is definitely associated with stress; the 'overlength' of consonants has hitherto likewise been associated with either primary or secondary stress.[20] The second syllable of such words as huvitav is subjectively unstressed. If phonemic quantity 3 can occur in a position in which it is not associated with a phonemic degree of stress, the interpretation of quantity 3 as an accent phenomenon should be revised.

If both allophones are assigned to quantity 2, it would become necessary to assume that the 'overlength' of the first syllable of such words as saata is associated only with the vowel, not with the consonant. This appears intuitively unacceptable; the reaction of the native speaker is that the /t/'s in such words as saata and katta are equivalent, in the same way as the /a/'s in saata and saada are equivalent.[21] In words such as huvitav, it would become necessary to explain the realization of /t/ in quantity 2 with reference to the quantity of the preceding disyllabic sequence, which would entail cumbersome rules: /t/ is realized as having a relatively longer allophone of quantity 2 after a disyllabic sequence whose first syllable is in syllabic quantity 1 or or 2, and as having a relatively shorter allophone of quantity 2 after a disyllabic sequence whose first syllable is in syllabic

quantity 3.[22] It would still be necessary to specify that contrasts of quantities 1, 2, and 3 are possible in the given position after a disyllabic sequence whose first syllable is in quantity 3, and only quantity 1 and 2 (in the allophonic manifestation specified here) are possible after an initial disyllabic sequence whose first syllable is in quantity 1 or 2.

Both suggestions violate the intuitive feeling that overlength is somehow associated with stress. The lack of contrast between quantities 2 and 3 in both positions under consideration also makes an assignment of one of the non-contrastive durations to phonemic quantity 2, the other to phonemic quantity 3, seem quite arbitrary. I would like to propose an alternate solution: the acceptance of neutralization of quantity oppositions under specifically defined circumstances. In those positions the segmental quantity of the phonemes should simply remain unmarked. The indication of the segmental quantity of each phoneme is only necessary if the goal of the phonemicization is a strictly linear phonemic transcription. If the hierarchial principle is adopted, the manifestation of quantities can be defined with regard to position within a higher-level unit, and it becomes unnecessary to specify the segmental quantity of every phoneme in a linear sequence.[23] The problem of neutralizations is considered further in the paragraph dealing with consonant clusters.

7.2. Initial consonants

Utterance-initial consonants were generally found to be longer than intervocalic consonants in quantity 1. No contrasts occur in utterance-initial position.

Word-initial consonants depended to a great extent on the degree of stress received by the word within the sentence. In sequences in which a word-initial consonant followed a word-final vowel, the stressed word-initial allophones had durations whose averages fell between the average values for intervocalic quantities 1 and 2. The presence of a consonant in such an intermediate quantity, combined with other factors, evidently characterizes the onset of a new word. Such intermediate quantities were also observed in word-initial consonants following a word-final consonant.

In the case of unstressed words beginning with a consonant, the allophones occurring in initial position had the durations and other phonetic characteristics of consonants in intervocalic quantity 1. There were numerous occurrences of initial allophones of /t/ and /k/ that appeared either fully voiced or fricated in the same manner as some intervocalic allophones in quantity 1. The

evidence suggests that in these instances the word has been fused with the preceding word into a higher-level phonological unit.

The materials collected and analyzed during the study contain a considerable amount of information about consonant + consonant sequences in which the presence of a syllable boundary contrasts with the presence of a superimposed word boundary. In such sequences the presence of a word boundary could be deduced from the somewhat greater length of the word-initial consonant. However, the word-initial consonant was longer than the syllable-initial consonant only when the word was stressed. No difference was found between intervocalic clusters on the one hand and unstressed sequences of word-final consonant + word-initial consonant on the other hand. This constitutes partial evidence for the assumption that the word boundary in such sequences has been obliterated, and that the words themselves have become part of a phonological phrase.

It is an interesting fact that segmental conditioning of the duration of consonants often takes place across word boundaries without regard to sentence stress. It was found in the study of intervocalic clusters that plosives had particularly short syllable-initial allophones in sequences in which they were preceded by nasals. Similar short manifestations of word-initial plosives were observed in sequences in which the preceding word ended in a nasal. The degree of sentence stress on the word beginning with the plosive was apparently irrelevant. Some examples of this phenomenon are shown on the figures. Utterance 133, reproduced on Figure 2, contains the intervocalic cluster /n/ + /k/ in the word kinga and the same sequence, separated by a word boundary, in on katki. The initial allophone of /k/ in katki is not much longer than the syllable-initial allophone in kinga, although katki carries primary sentence stress. Of course, quantity patterns are only part of the boundary signals; as is evident from the spectrogram, the boundary in the sequence on katki is clearly manifested by the presence of a dental rather than a velar allophone of /n/.

In syllable-initial position, the average durations of allophones of the various consonants were somewhat longer than the intervocalic occurrences in quantity 1. An exception is the average duration of syllable-initial /p/. In this case the numerous clusters consisting of the sequence /m/ + /p/ may have influenced the average, since plosives have particularly short allophones after nasals.

In those clusters in which the plosives occurred in three phonemic quantities, the average durations were very close to the averages established for intervocalic position.

7.3. Final consonants

Only two contrastive quantities occurred in utterance-final position. The quantity of short utterance-final consonants may probably be considered equivalent to intervocalic quantity 1, although the actual manifestations were longer. The long consonants that occurred in utterance-final position seemed, at first glance, to belong to two groups. The quantity of one group was clearly identifiable with quantity 3 in intervocalic position. The other long occurrences had much in common with the ambiguously long occurrences between second and third syllables which were discussed above. The number of such occurrences was relatively small in the corpus, and not much material is available for comparison; it appears, nevertheless, that the rhythmic structure of such words as alet (397) is similar to that of such words as niit (362). The actual durations of the final consonants in these two words were practically identical: niit had a final /t/ with a duration of 24 csec, while the ambiguously long final /t/ in alet had a measured duration of 23.5 csec.

In sequences in which a word ending in a consonant was followed by a word beginning with a vowel, a short final consonant had all the characteristics of an intervocalic consonant in quantity 1. This may again be explained as the result of the application of the syllabification rule, according to which every nonfirst syllable has to begin with a consonant. When the word beginning with a vowel was unstressed, the two words were fused into a higher-level phonological unit. A typical example may be seen in the sequence lapsed on (149), Figure 2.

When a word ending in a consonant in quantity 3 was followed by a word beginning with a vowel, the consonant was produced as an intervocalic consonant in quantity 3: the syllable boundary occurred within the consonant, and the next syllable started with the rearticulated part of the plosive. In several instances, the rearticulation of the consonant was reflected as a spike on the spectrograms. Some examples are included on the illustrations. Figure 3 contains the sequence ork on (264), in which the /k/ in quantity 3 appears distributed between the two syllables, and the following word thus is linked to the preceding one. Figure 7 contains two instances. In the sequence luustik oli (498), /k/ was pronounced as a short geminate; in puutikk oli (500), the second component of the compound evidently received primary stress, and the word-final /k/ in quantity 3 was produced as intervocalic /k/ in quantity 3, with a rearticulation of the /k/ at the beginning of the next syllable.

There were no instances in which a sequence consisting of a word-final consonant followed by a word-initial vowel would

have been realized with a phonetically manifested syllable boundary after the consonant. At least in the pronunciation of this speaker, the morphological structure of the sequence did not affect the syllabification rule according to which an intervocalic consonant starts the following syllable. The 35 spectrograms presented on the illustrations contain a number of clear positive examples and no negative example for the functioning of the rule.[24]

The problem of syllable-final consonants, i. e. consonants as first members of an intervocalic cluster, is rather complicated. The question concerns the identification of an overlong syllable-final consonant, such as /t/ in katki, with phonemic quantity 2 or 3.

In an earlier publication[25] I identified the quantity of /t/ in such words as katki with phonemic quantity 2, using the following reasoning. If disyllabic words are divided into classes according to the length of their first syllable, such words as katki and kotti belong in the same class; in a very real sense, their first syllables are quantitatively equivalent. Assuming that the syllable boundary falls before the last element of an intervocalic cluster and before the third mora of an intervocalic quantity 3 consonant, the syllable-final /t/ in katki is equivalent to the first two morae of /t/ in such a word as kotti. There are enough examples of spectrograms with spikes within the intervocalic consonant in quantity 3 to lend support to the assumption that the syllable boundary falls within the consonant. The spike indicating the release of the first consonant in such clusters as /tk/ in katki occurs usually in the same time segment as the spike in an overlong consonant (provided that both the overlong consonant and the cluster show a spike, which does not happen in every case).

Measured durations offer some further phonetic evidence in support of identifying the first element of the cluster in katki with quantity 2. Intervocalic consonants in quantity 3 are longer than syllable-final overlong consonants. The difference is approximately equal to the duration of the same consonants in syllable-initial position. In other words, the duration of overlong consonants in syllable-final position plus the duration of consonants in syllable-initial position corresponds approximately to the duration of intervocalic consonants in quantity 3.[26]

The possible identification of syllable-final overlong consonants with consonant quantity 2 is also supported by the fact that the duration of final plosives in monosyllabic words is considerably longer than the duration of syllable-final overlong consonants.[27] If word-final overlong consonants are assigned to quantity 3, the total intervocalic cluster might be considered as being

in quantity 3, and the phonetically shorter syllable-final consonant might be assigned to quantity 2.

One reason against identifying syllable-final overlong consonants with quantity 2 is the fact that consonants in intervocalic quantity 2 are articulated as short geminates and contain a syllable boundary. This is definitely not the case with consonants that constitute the first component of an overlong consonant cluster.

Some of the phonetic data gathered during an earlier study[28] might be interpreted as offering evidence for identifying the syllable-final overlong consonant with quantity 3. This would, however, require a reinterpretation of intervocalic quantity 3. The average durations of intervocalic consonants in the three phonemic quantities were established during that study as 7 csec for quantity 1, 15 csec for quantity 2, and 34 csec for quantity 3. Thus the time ratio for consonant durations might be expressed as 1:2:4, or even as 1:2:5. In an approach in which phonological morae are identified with units of measured duration, the intervocalic quantity 3 should really be interpreted as containing four morae. Thus the consonant cluster in katki might likewise be considered to contain four morae, of which the first three are associated with the syllable-final overlong /t/.

It is well known that the duration of word-initial consonants is non-contrastive and therefore phonemically nonsignificant. This observation might be extended to apply also to syllables, i. e. the duration of syllable-initial consonants might be considered phonemically irrelevant. Then the intervocalic consonant quantities should be reinterpreted by subtracting from them (both phonetically and phonemically) the duration of the part that constitutes the first consonant of the following syllable. If this principle is applied consistently, the syllable-final consonants of such words as katki and kotti might both be assigned the phonemic quantity 2. Phonemic quantity 3 would then be restricted to word-final position.

None of the solutions appears completely satisfactory. In many cases, the assignment of phonemic quantity to members of intervocalic clusters seems to require arbitrary decisions. As in the case of ambiguous intervocalic quantity discussed above, I propose to consider certain intervocalic clusters as a special case in which some of the quantity oppositions are neutralized. If in a cluster as /tk/ only two contrastive quantities are possible,[29] the conditioning factors which determine the neutralization of the opposition should be specified, and the identification of the quantity of a member of a cluster with the quantity degree of the same consonant in intervocalic position between the first

and second syllable is unnecessary. As was mentioned above, the specification of the segmental quantity of each segment in a linear sequence is only necessary if phonology is approached as if it constituted a single level. If it is admitted that quantity may function at various levels, the rules which apply at a lower level may be overruled when the lower-level unit becomes part of a higher-level unit. Thus in many instances segmental quantity is subordinated to syllabic quantity, and syllabic quantity is subordinated to patterns characterizing word-level units. Word-level units, in turn, undergo various phonological modifications when they become part of phonological phrases. When quantity ceases to be contrastive, its identification with a contrastive quantity can only conceal its true nature.

7.4. Interrelations between vowel and consonant quantity

During this investigation, attention has been concentrated on the quantities of consonants. It has been emphasized repeatedly that in the overall patterns consonant quantity is combined with vowel quantity in the creation of quantity patterns that characterize higher-level phonological units. Only if the consonant quantity patterns are correlated with the simultaneously manifested vowel quantity patterns, can the description be complete.

The patterns discovered during this study nevertheless make it possible to draw a few conclusions about the phonological structure of an Estonian utterance and the part played in it by its individual constituents. The utterance is built up of syllables; each syllable begins with a consonant.[30] The requirement that each nonfirst syllable begin with a consonant causes the replacement of word-final consonants with intervocalic consonants in sequences in which a word-final consonant is followed by a word-initial vowel. In unstressed words, initial consonants following a word-final vowel may likewise be replaced with intervocalic consonants in quantity 1; as a result, phonological phrases are formed in which the fused word loses its own sentence stress. However, in cases in which word-final consonants are carried over to start the next syllable, the word beginning with a vowel need not lose its own stress.

This suggests that the formation of phonological phrases is primarily determined by the working of the syllabification rule. Words may lose their distinctly manifested boundaries without losing their sentence stress. The number of primary stresses within a phonological phrase is not limited to one, and words with primary stress do not form nuclei within the sentences that attract other words to form phonological phrases centered around a primary stress.

This assumption is supported by the fact that certain segmental syllabification rules are applied to word boundaries without regard for stress. Short allophones of plosives occurred in sequences consisting of nasal + plosive, regardless of whether the sequences occurred in intervocalic position within words or contained a word boundary. In the latter case, the words beginning with these short plosive allophones could carry a much higher degree of sentence stress than the preceding word, which very often was completely unstressed.

In sequences of words ending in a vowel followed by words beginning with a consonant, stress was found to be closely connected with the manifestation of word boundaries. In such sequences, the use of an intervocalic allophone in quantity 1 appeared correlated to the lack of sentence stress. Initial consonants of words carrying a noticeable degree of sentence stress were found to be realized in a characteristic intermediate quantity rather than in one of the three intervocalic quantities. Except for the sequences of nasal + plosive and possibly some others not studied in the present context, this applies also to initial consonants of words preceded by words ending in a consonant.

7.5. Outlook for further research

The question of the role of quantity within the phonological system of Estonian is still far from having been completely solved. The test materials contained various other occurrences of the consonants which have been described above, particularly in various other clusters and in sequences involving clusters. The study has revealed that the number of utterances was not adequate for studying some aspects of the problem, and new material should be devised and recorded to test the insufficiently supported arguments. Patterns emerging from the analysis of vowels should be compared with those associated with the consonants.[31] It would be useful if several other informants would record the test sentences, and if a larger group of speakers would record a group of selected sentences, so that the range of variations could be established with greater assurance and validity. The patterns that underlie the apparent complexity are there to be discovered; it is hoped that the present paper may constitute a small contribution toward their ultimate elucidation.

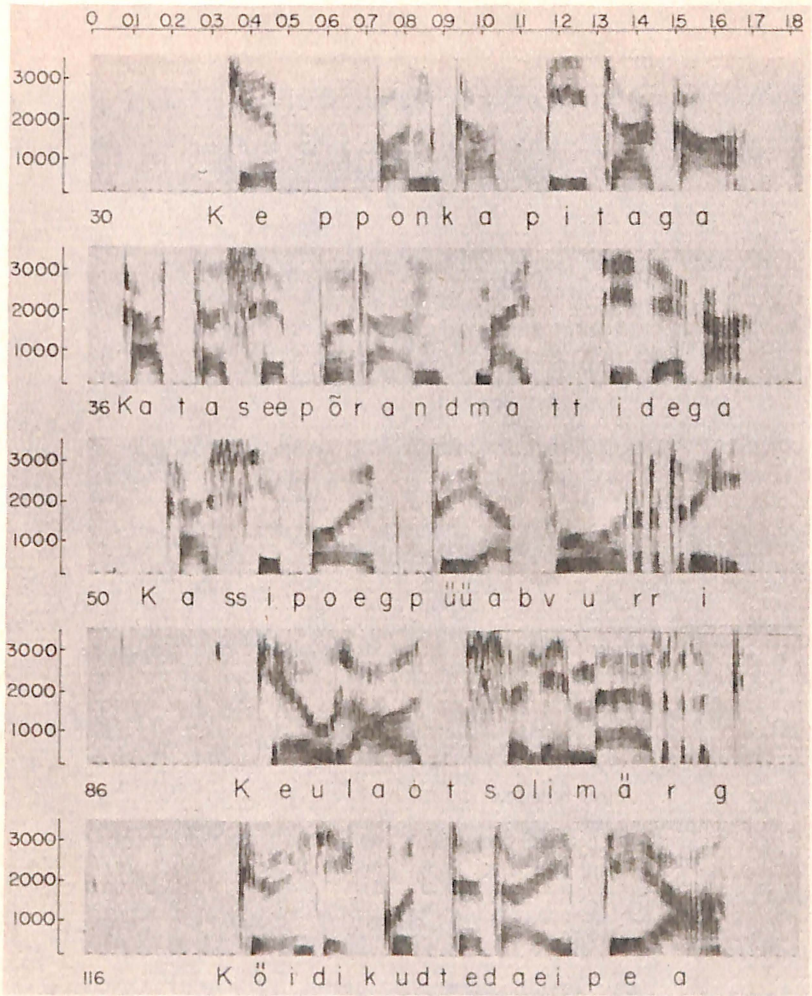


Figure 1

Broad-band spectrograms of sentences 30, 36, 50, 86, and 116. The scale on the left indicates frequencies in cycles per second, the scale on top shows durations in seconds. Conventional spelling is used for identifying the utterances; the letters are placed in such a manner as to make it possible to relate the sounds of the utterances to the acoustic segments.

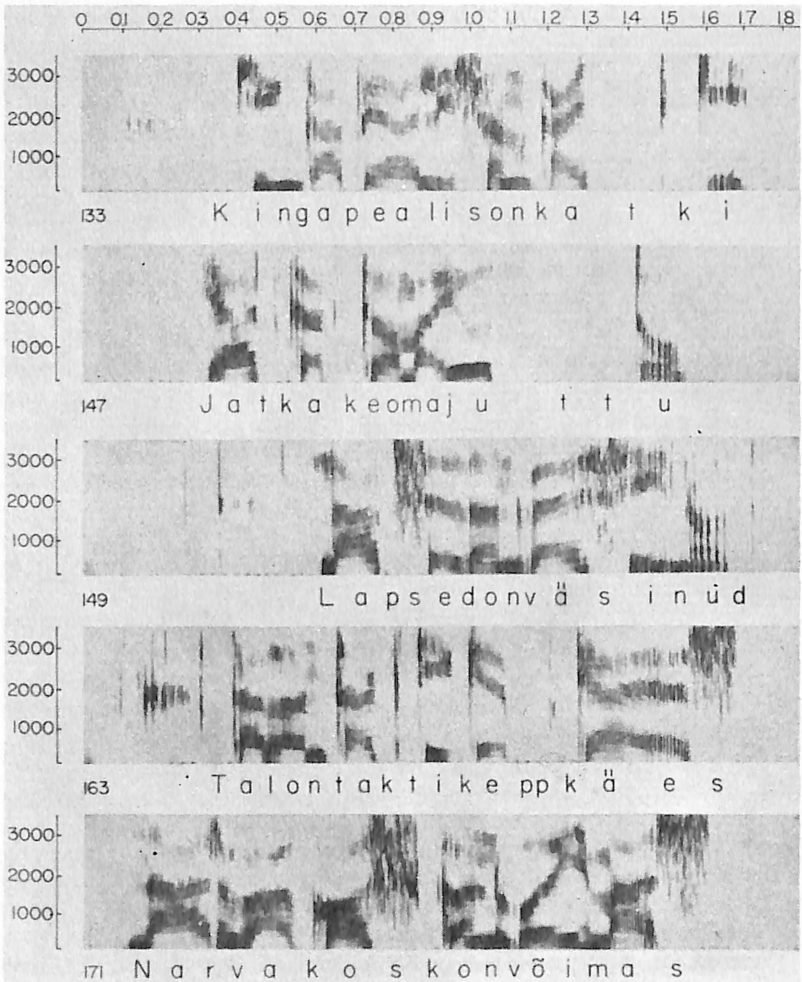


Figure 2

Broad-band spectrograms of utterances 133, 147, 149, 163, and 171.

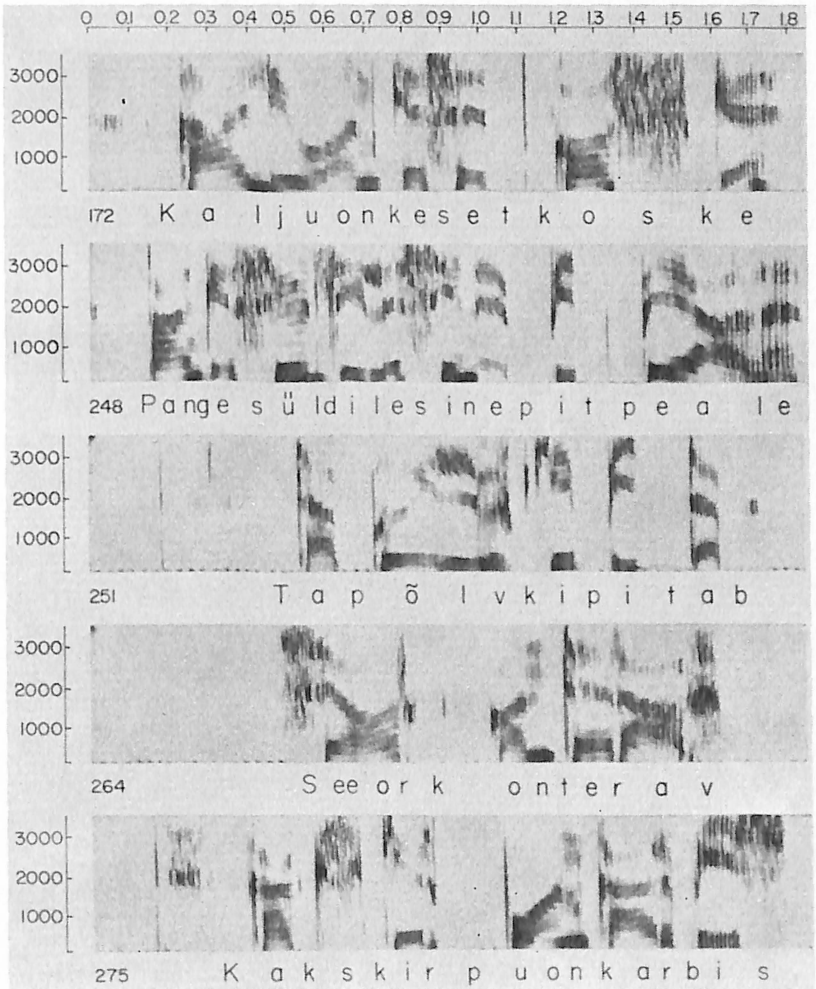


Figure 3

Broad-band spectrograms of utterances 172, 248, 251, 264, and 275.

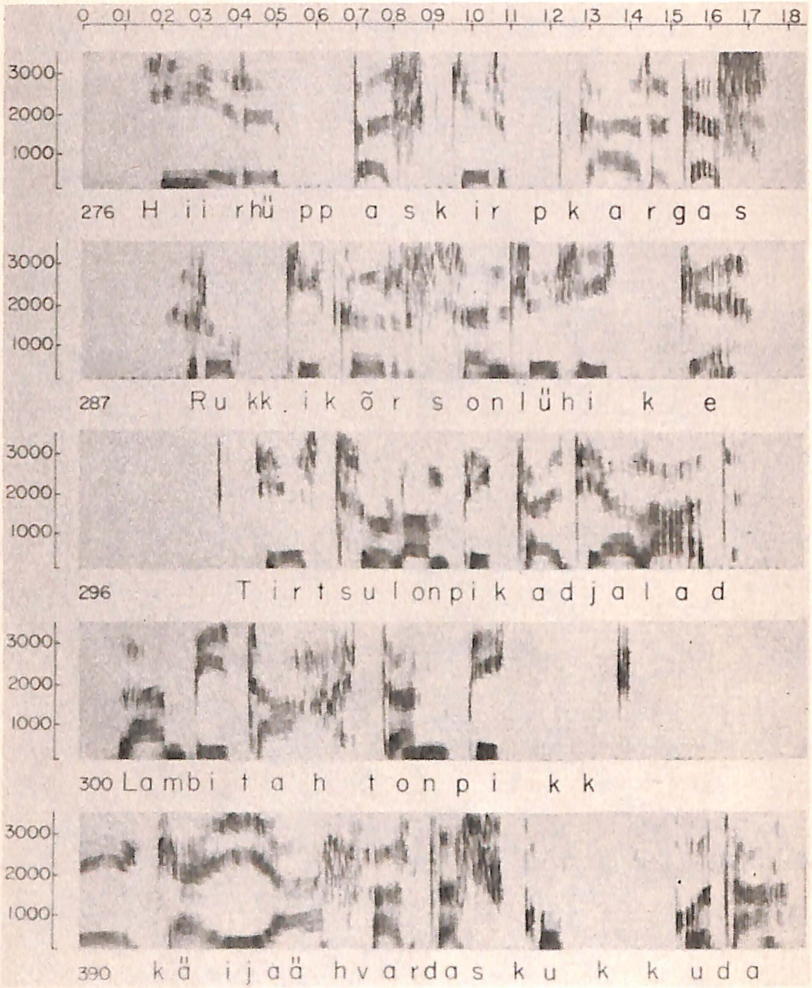


Figure 4

Broad-band spectrograms of utterances 276, 287, 296, 300, and 390.

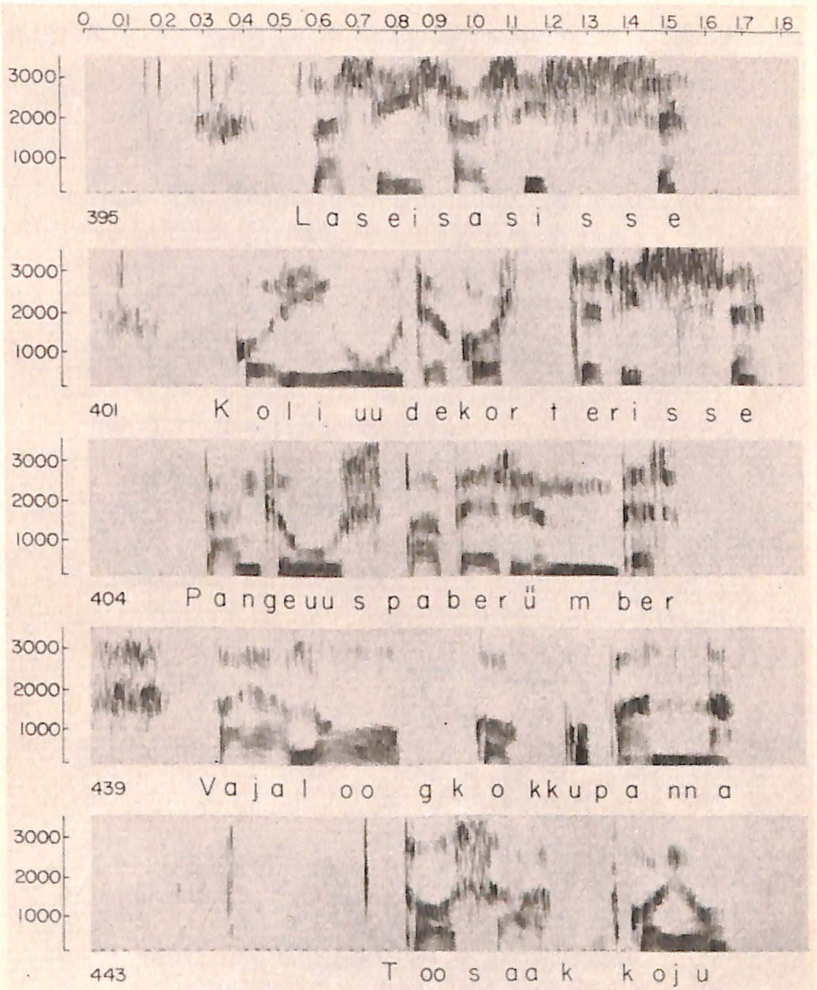


Figure 5

Broad-band spectrograms of utterances 395, 401, 404, 439, and 443.

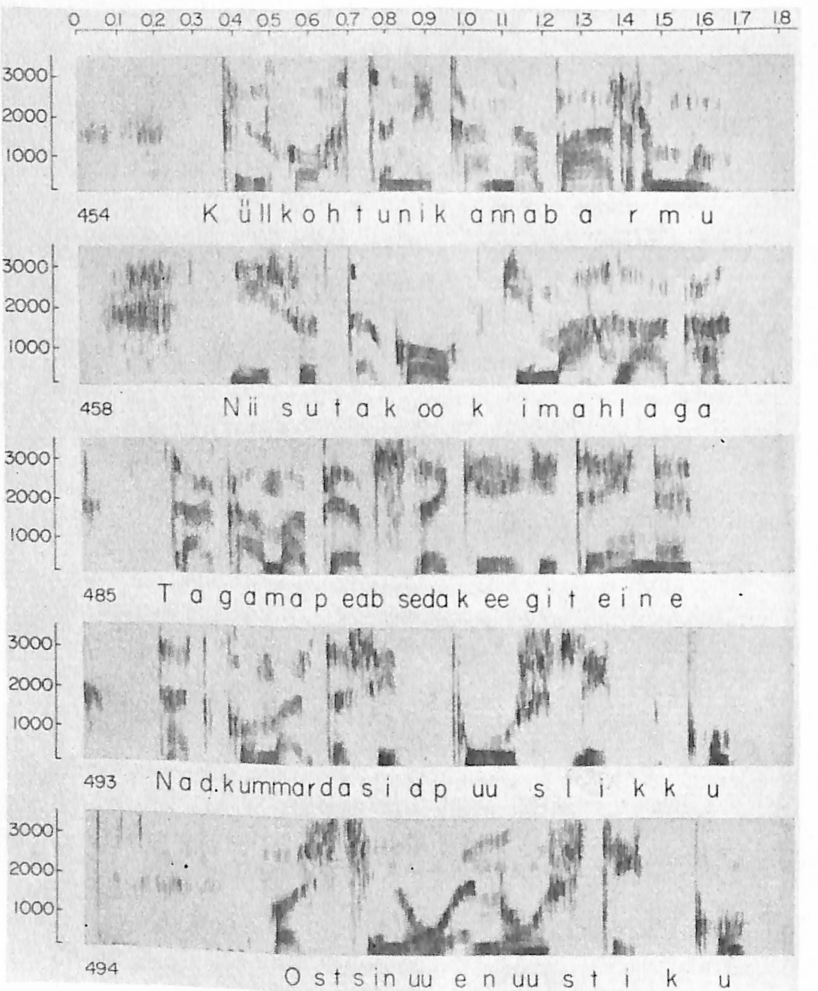


Figure 6

Broad-band spectrograms of utterances 454, 458, 485, 493, and 494.

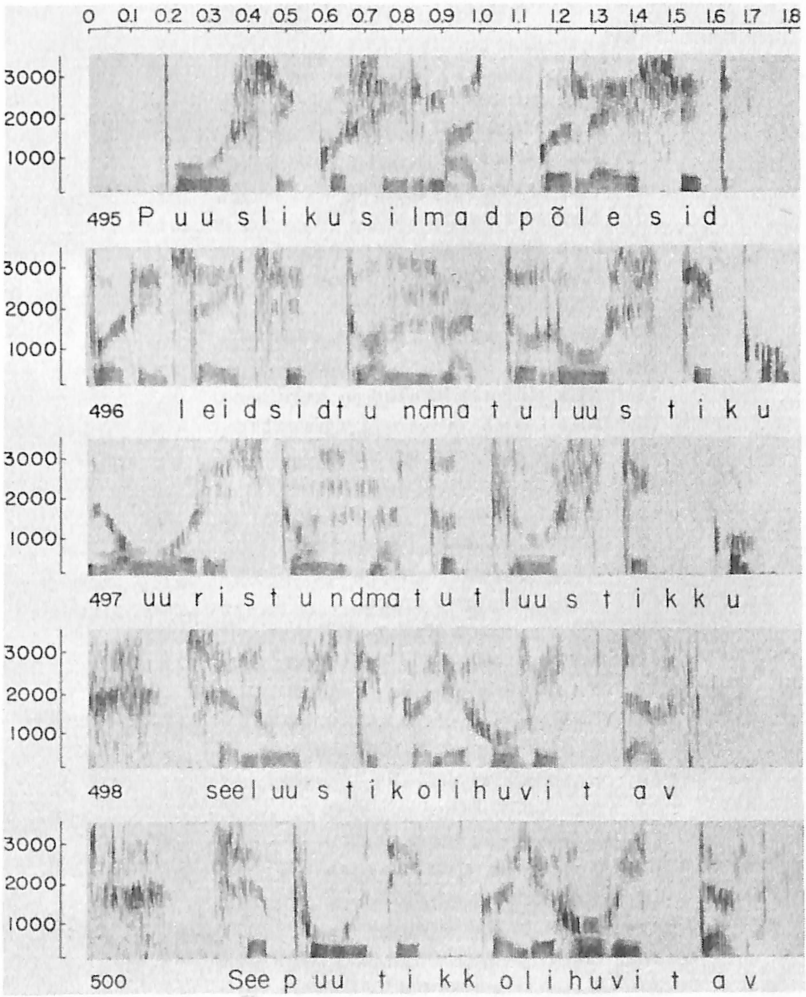


Figure 7

Broad-band spectrograms of utterances 495, 496, 497, 498, and 500.

Appendix

List of 500 sentences recorded and analyzed during the investigation

1. Kas mina või sina?
2. Kas Miina või Liisa?
3. Kas tahad viina või piima?
4. Kas tere või jumalaga?
5. Kas see veereb või libiseb?
6. Kas see veeres või kukkus?
7. Kas see on käru või vanker?
8. Mis sa must näägutad.
9. Mis sa sest käänad ja väänad.
10. Kas see on kala või liha?
11. Mis sa sest kaalud ja venitad.
12. Kas tahad saagi või kirvest?
13. Viska see koli minema.
14. Kas ta on koolis või kodus?
15. Kas ta läks kooli või kiriku?
16. Vaata kui kuri nägu tal on!
17. Kukk oli kuuri katusel.
18. Pane see lind puuri.
19. Küsija suu pääle ei lööda.
20. Milles teda süüdistatakse?
21. Tema pole milleski süüdi.
22. Mis sa tast lömaks astusid.
23. Ta on ju kuulus löömamees.
24. Hakati kiriku kella lööma.
25. See on ju kõva kui kivi.
26. Paluge võõras tuppa.
27. Ta reisis võõrale maale.
28. Lõpuks ometi vaba!
29. Tuba on segamini.
30. Kepp on kapi taga.
31. Kas talle lõppu ei tulegi?
32. Mehed koondusid rivvi.
33. Kuhu see võti kadus?
34. Jukul on tutiga müts.
35. Lumi krudises.
36. Kata see põrand mattidega.
37. Pane need kannid kotti.
38. Kannata natuke!
39. Vennal on neli konna.

40. Konnad hüppasid tünni.
41. Too mulle siniseid lilli.
42. Kes teid siia kokku kutsus?
43. Kes sääl kõnnib kellega?
44. Tormi käes murduvad tammepuud.
45. Sinna on viissada sammu.
46. Vang pandi kongi.
47. Seal ta istub vangikongis.
48. Laske mind sisse!
49. Kassapidaja loeb raha.
50. Kassipoeg püüab vurri.
51. Vurriluu kukkus laua alla.
52. Ta läks omaga sassi.
53. Püsi ometi paigal!
54. Millise kella ta valis?
55. Puhusin seebimulle.
56. Anna see rohi mulle.
57. Ta räägib tsehhi keelt.
58. Ma ei tunne ühtegi tsehhi.
59. Selle me unustasime ära.
60. Millal see kord lõpetatakse?
61. Ilma sõpradeta on siin igav.
62. See läheb ju aina igavamaks.
63. Ta saabumiseni on veel aega.
64. Ilma hooplemata peaks kah saama.
65. See on ettevaatamatuse tagajärg.
66. See kiri on vastamata.
67. Küll oli teil neid kõnelemisi!
68. Oli siis neid nägemisi ja tegemisi.
69. Nende heledate päevadega.
70. Aastate möödudes.
71. Langenud kangelaste mälestuseks.
72. Tuli oodatud külalisi.
73. Kuhu ta nende raamatutega läheb?
74. Püüa oma viisakusetust parandada.
75. See rabas oma ootamatusega.
76. See on üks parandamatu kurjategija.
77. Millal seda seletatakse?
78. Lauda uks on lahti.
79. Lehm läks lauta.
80. Ema katab lauda.
81. Mis sa must kiusad.
82. Koer kiunub.
83. Koer kiunus.
84. Tõin liua.

85. Too liuda!
86. Keula ots oli märg.
87. Paranda keula!
88. Võta mind õue kaasa.
89. Peida see põue.
90. Tõin õuna.
91. Söö õuna.
92. Kuhu ta sõuab?
93. Lõunatund on käes.
94. Aeg on lõunat süüa.
95. Kass käunub haledasti.
96. Kass käunus haledasti.
97. Meri lainetab.
98. Armastan kõrgeid laineid.
99. Tõin selle aine.
100. Eine on laual.
101. Tõin eine.
102. Tulge meile!
103. Poisid on loiud.
104. Loidus on halb.
105. Ei ole kuiva ilma.
106. Ilmad on kuivad.
107. Näita seda nuia.
108. Nuiamehed tulevad.
109. See on võimatu.
110. Osta võid.
111. Nõiad istuvad aias.
112. Kus sa käisid?
113. Kus ta käis?
114. Tahan käia.
115. Tõin käia.
116. Köidikud teda ei pea.
117. Lehm pandi köide.
118. Küünal on müüa.
119. Süütasin küünla.
120. Müüja on küürus.
121. Pane sall kaela!
122. Mul on sall kaelas.
123. Koerad kaklevad.
124. Sööda koera!
125. Nõelusin sukka.
126. Pane nõelale niit taha.
127. Otsi nõela!
128. Kuhu sa sõela panid?
129. Ahi köeb.

130. Ahjus on söed.
131. Päevane kutsikas.
132. Kasuta päeva.
133. Kinga pealis on katki.
134. Pane lapp peale.
135. Kuhu sa noad panid?
136. Load on valmis.
137. Panin lehmale lõa kaela.
138. Ta pöab lammast.
139. Seo nad kokku.
140. See oli teo-orjus.
141. Lõoke laulab.
142. Käod ei ehita pesa.
143. Lao need pakid reele.
144. Ao valgusel.
145. Kitsed lõid kepsu.
146. Igaüks kardab katku.
147. Jatkake oma juttu!
148. Laps on väsinud.
149. Lapsed on väsinud.
150. Retk oli väsitav.
151. Igal jutul on ots.
152. Omad vitsad peksavad.
153. Puude ladvus kohiseb tuul.
154. Tuul kõigutab puude latvu.
155. Puu latv murdus.
156. Plikal on pikad patsid.
157. Pane müts pähe!
158. Ega sa mu mütsi võtnud?
159. Üks rohutirts läks kõndima.
160. Miks sa seda ära ei maksnud?
161. Küll ma maksan.
162. Koorijuht lööb takti.
163. Tal on taktikepp käes.
164. See on üks veider sekt.
165. Mul on see tekst peas.
166. Laastud langesid põrandale.
167. Ulata see laast mulle!
168. Kas sa ta last nägid?
169. Ta on laisk.
170. See on laiskuse tagajärg.
171. Narva kosk on võimas.
172. Kalju on keset koske.
173. Seal on vanamehe osm.
174. See on üks vilets osmik.

175. Tänavu on halb viljakasv.
176. Midagi ei kasva.
177. Puu küljes on käsn.
178. Ta peseb käsnaga tahvlit.
179. Üks kask meil kasvas õues.
180. Nägin ilusat kaske.
181. Laeva mast murdus.
182. Mõlemad mastid murdusid.
183. Kumba kasti sa tahtsid?
184. Kumb king pigistab?
185. Täna on umbne ilm.
186. See pliiats on tömp.
187. Teritasin tömpi pliiatsit.
188. Pane see komps põrandale.
189. Pane oma kompsud põrandale.
190. Minu vend seda ei teinud.
191. Kas sa mu venda nägid?
192. Kas see on pint või koot?
193. Ma töötan pindaga.
194. Me töötame pintadega.
195. Kütt praadis karu kintsu.
196. Karu kints oli rasvane.
197. Karu kintsul oli veider maik.
198. Koer närib konti.
199. Viska see kont minema.
200. Viska need kondid minema.
201. See kaalub seitse untsi.
202. Printsi hobune on metsik.
203. Teda ratsutada on kunst.
204. Seda kunsti ma ei tunne.
205. Hanged katavad maad.
206. Ta kaotas kinga hange.
207. See hang on kõrge.
208. Ma kingin sulle õnge.
209. Miks sa mulle õnge ei kinkinud?
210. See oli ilus kink.
211. Jõin lonksu vett.
212. Võta veel üks lonks.
213. Kus see sidumise punkt oli?
214. Haavatu läks sidumise punkti.
215. Punktid ja kriipsud.
216. Ta otsib õngekonksu.
217. Ta ei maksa oma võlgu.
218. Ta võlg on maksmata.
219. Küünal vilgub.

220. Küünal vilkus.
221. See pulk on lühike.
222. Ta silmad on kinni.
223. Tal on kolm venda.
224. Õpetaja kergitas kulme.
225. Kõik pole kuld mis hiilgab.
226. See tõld on kaks sülda pikk.
227. Poiss näitas keelt.
228. Ta vahtis laua alt välja.
229. Otsime tuulte eest varju.
230. Puistasin tuha tuulde.
231. Pilved on taevas.
232. Täna pilvitab tugevasti.
233. Mäe nõlv oli järsk.
234. See on halb tegu.
235. Ta tunneb end halvasti.
236. Seisab nagu tulp.
237. Tulbad kukkusid ümber.
238. Kaltsud on räpased.
239. Ta ostab kaltse ja konte.
240. Pööra teine külg.
241. Palgid on rasked.
242. Kilk laulab koldel.
243. Ta sõi silku ja leiba.
244. Täna on külm ilm.
245. Nöör läks sõlme.
246. Silmad on väsinud.
247. Sööge veel sülti.
248. Pange süldile sinepit peale.
249. Kuidas sült maitseb?
250. Ta lõi oma põlve ära.
251. Ta põlv kipitab.
252. Talumees külvab nisu.
253. Siin on ta kilp ja mõõk.
254. Ega sa ta kilpi ei näinud?
255. Siin on ta kilbid ja odad.
256. Need on võlts ehted.
257. Ta võltsis mu allkirja.
258. See dokument on võltsitud.
259. Ta pulss on korratu.
260. Ta pulsil pole midagi viga.
261. Arst katsus pulssi.
262. See org on ilus.
263. Kurg lendab kõrgel.
264. See ork on terav.

265. Tüdruk pandi nurka.
266. Laps seisab nurgas.
267. Veel üks kord.
268. Veel kaks korda.
269. Nägin tormist merd.
270. Part lendab.
271. Nägin parti.
272. Pardil on ilusad suled.
273. Isal on kõrb hobune.
274. Vaata neid kase urbi.
275. Kaks kirpu on karbis.
276. Hiir hüppas, kirp kargas.
277. Parm lendas.
278. Lehm kardab parmu.
279. Tal on pikad sõrmed.
280. Tal on suured kõrvad.
281. Ta puhub sarve.
282. Sarv on must nagu tõrv.
283. Põrsal on kõrs suus.
284. Põrsas kirtsutab kärssa.
285. Põrsa kärss on must.
286. Roosi vars on okkaline.
287. Rukki kõrs on lühike.
288. Rutt korjas rukkikõrsi.
289. Sööge pirne.
290. Pirnid on kõvad.
291. Kas see pirn on pehme?
292. Arstil on vähe aega.
293. Ega ta arsti ei kutsunud?
294. Kulmude vahel on korts.
295. Poiss nägi rohutirtsu.
296. Tirtsul on pikad jalad.
297. Ta kukkus järsku.
298. See koht on paha.
299. Otsin uut kohta.
300. Lambi taht on pikk.
301. Puhasta lambi tahti.
302. Küll on hea lõhn!
303. Mis lõhnad need on?
304. Siin pole mingit lõhna.
305. Õhk on puhas.
306. Armastan puhast õhku.
307. Lehm on kõhn.
308. Lehmal on muhk otsa ees.
309. Perenaine lüpsab lehma.

310. Pops oli kehv.
311. Põllud on kehvad.
312. Koer näitab kihvu.
313. Veame kihla.
314. Pohlad on mahlased.
315. See on jõhvika mahl.
316. Ta võttis kihvti.
317. Need on kihvtised marjad.
318. Võta mind majja kaasa.
319. Võta mind õue kaasa.
320. Võta mind linna kaasa.
321. Võta mind tallu kaasa.
322. Võta mind ojja kaasa.
323. Võta mind kinno kaasa.
324. Võta mind randa kaasa.
325. Soovime palju jõudu!
326. See oli kõue kärgatus.
327. Kuulsin hirmsat kõue.
328. See on ta ammune nõue.
329. Ta nõuab liiga palju.
330. Ta ei tohiks seda nõuda.
331. Tegin lõuna valmis.
332. Lõuna on laual.
333. Panin lehma lõõga.
334. Mis ta nii lõugab?
335. Ta lõual on punane plekk.
336. Millal ta koju jõuab?
337. Ta on õues.
338. Ta on aias.
339. Ta on majas.
340. Ta on maias.
341. See on liigne maius.
342. Ta raius mändi.
343. Ära raiu õunapuud!
344. Oli kole rajuilm.
345. Hauas on külm.
346. Saunas on soe.
347. Kui kaua nad lauas istuvad?
348. Püüa see konn kinni!
349. Mis ma tast püüan.
350. Kas tahad saia süüa?
351. Aina need saiad.
352. Ega täna vihma ei saja?
353. Hüppasin üle laia kraavi.
354. Ta tahtis nuia ära viia.

355. Ma talle nuia ei anna.
356. Tulge siia!
357. Ta uinus juba.
358. Ta ostis pruuni kuue.
359. Anna mulle juua!
360. Ta võttis teise suuna.
361. See on jää-äärne kivi.
362. See on jõe-äärne niit.
363. See on maa-alune elamu.
364. Ta on kuulus kuu-uurija.
365. Rähn on puu-uuristaja.
366. Maja alune on niiske.
367. See on maja-alune kelder.
368. Hüljes on vee-elukas.
369. Ta on vana põranda-alune.
370. Ta elas teo-orjuse ajal.
371. Ta oli sõja-aegne laps.
372. See on naljakas.
373. Pall libises.
374. Seebimull lõhkes.
375. Laul lõppes.
376. Meestesumm möödus.
377. Kuidas leem maitses?
378. Tõnn naeris.
379. Seal on sada sauna.
380. Saada Ants tundi.
381. Kas tahad lüüa saada?
382. Vaja sind kooli saata.
383. Ära seda kinni kata!
384. See tuleb hoolsasti katta.
385. Need tuleb kokku koguda.
386. Ta ei kokuta enam.
387. Neid marke enam ei koguta.
388. Ta ei nooguta mulle.
389. Kookude otsas on panged.
390. Teekäija ähvardas kukkuda.
391. See on parte peal.
392. Pereisa otsustagu ise.
393. Ta on nüüd hoopis teine inimene.
394. Armastan tuuleiile.
395. Lase isa sisse.
396. Pühi tare esine puhtaks.
397. Homme teeme alet.
398. Toome aamid tuppa.
399. Tulease kaeti mullaga.

400. Ta nägi unes isatalu.
401. Koli uude korterisse!
402. See oli imelik.
403. Ärge ulatage talle kätt!
404. Pange uus paber ümber!
405. Eks ta jää ise koju.
406. See jäi jalgu.
407. See jäi alla.
408. Ära jää ette.
409. Ta jäi ilma.
410. Ära jää uniseks.
411. Eks ta jää omale.
412. Vanaisa võttis laisa naise.
413. Saiaga meelitatakse lapsi.
414. Anna isale süüa!
415. Las ta jagab need saiad välja.
416. Sai aga talle ei maitse.
417. Ta on selle linna elanik.
418. Ei lasta elada.
419. Ei taheta erineda.
420. Ei lasta eemalduda.
421. Ära seda usu!
422. See on ebausk.
423. Too isale juua!
424. Too emale enne!
425. Too aabits siia!
426. Ta koukis augu tühjaks.
427. Ta kougib sõrmega nina.
428. Too und jõest välja!
429. Nisuiva langes mulda.
430. Selleks kulus terve eluiga.
431. Söö enne puder ära.
432. Söö ise, kui tahad.
433. Too onule klaas vett!
434. Töö algab homme.
435. Ta pandi istuma.
436. Ta tuli ise.
437. Vii isale klaas vett!
438. Ta tuli Iirimaalt.
439. Vaja loog kokku panna.
440. Pane saag kasti.
441. Pane saak kasti.
442. Too saag koju.
443. Too saak koju.
444. Ta vaakus hinge.

445. Too pakk koju.
446. See on suur ratas.
447. Ratta kodar ragises.
448. Kepp seisab nurgas.
449. Laps istub nurgas.
450. Kuidas ilm on?
451. Kuidas silm on?
452. Pane lapp alla.
453. Ära karda parmu.
454. Küll kohtunik annab armu.
455. Anna talle andeks!
456. Sa annad talle andeks.
457. Sa annad alla.
458. Niisuta kooki mahlaga.
459. Mahl aga maksab raha.
460. Rahvaga ei maksa vaielda.
461. Vähke püüti kahvaga.
462. Kahv aga kukkus vette.
463. Vihmaga ei saa heina teha.
464. Vihm aga jääb varsti järele.
465. See on piksevihm.
466. Käsn aga läks kaduma.
467. Sellest ei saa kasu.
468. Pildile pandi suur raam.
469. See on tõesti suur aam.
470. Pildil on puuraam.
471. Haual on puurist.
472. Ta tuli kuurist.
473. Haual on suur rist.
474. Ahi läheb kuumaks.
475. Kuu-maks on liiga kõrge.
476. Need on kodumaa metsad.
477. Peaksime kuduma minema.
478. Puumaa saab teisele pojale.
479. Tagamaa toodab toormaterjale.
480. Saatma ta mind ei tulnud.
481. Majake seisab raatmaa rajal.
482. Tootma see tehas niipea ei hakka.
483. Peame looma paremad töötingimused.
484. Kogu soomaa muudeti põldudeks.
485. Tagama peab seda keegi teine.
486. Kas te jääte kella viieni?
487. See on vaid jääde parematest aegadest.
488. Jäätee peaks libedam olema kui lumetee.

489. Millal te koju tulete?
490. Tulede valgus tuhmus.
491. Teritasin puutikku.
492. Viskasin puutiku põrandale.
493. Nad kummardasid puuslikku.
494. Ostsin uue nuustiku.
495. Puusliku silmad põlesid.
496. Kaevurid leidsid tundmatu luustiku.
497. Teadlane uuris tundmatut luustikku.
498. See luustik oli huvitav.
499. See puuslik oli huvitav.
500. See puutikk oli huvitav.

Notes

1. The theory which underlies my concept of phonological units owes its inspiration to Kenneth L. Pike, although I use his theory with certain modifications. (cf. K. L. Pike, Language in Relation to a Unified Theory of the Structure of Human Behavior, Parts I, II, and III, Glendale, California, 1954, 1955, and 1960). According to the view reflected in the paper, language can be viewed as having a hierarchical structure in two aspects: phonologically and grammatically. In both hierarchies, there are successively larger units. An essential part of the description of a language is the description of the mutual relations between units of the phonological hierarchy (such as phonemes, syllables, and phonological phrases) and units of the grammatical hierarchy (such as morphemes and lexical words).

2. For a survey of the history of the problem of quantity in Estonian, cf. Ilse Lehiste, 'Segmental and Syllabic Quantity in Estonian', American Studies in Uralic Linguistics (Bloomington, 1960), pp. 31-82; Robert T. Harms, Estonian Grammar (Bloomington, 1962), pp. 143-162; and Valmen Hallap, 'Mõtteid eesti keele väldete foneetika kohta', Emakeele Seltsi Aastaraamat 8 (Tallinn, 1962), pp. 238-250. The summary offered here follows in broad outline the presentation given in my 'Segmental and Syllabic Quantity in Estonian'.

3. I have treated some problems connected with the structure of syllables, phonological words, and phonological phrases in Estonian in papers entitled 'Acoustic Studies of Boundary Signals', Proceedings of the Fourth International Congress of Phonetic Sciences, Helsinki 1961 (The Hague, 1962), pp. 178-187, and in 'Compounding as a Phonological Process', Proceedings of the Ninth International Congress of Linguists, Cambridge 1962 (The Hague, 1964), pp. 331-336.

4. In this article, the terms 'short', 'long', and 'overlong' will be used to refer to the phonetic characteristics (especially duration) of segments and syllables. The terms 'quantity 1', 'quantity 2', and 'quantity 3' will be applied when the segments or syllables are definitely assigned to a phonemic quantity. For a discussion of the desirability of making this distinction explicit, cf. Valmen Hallap, 'Fonoloogiline etüüd eesti keele väldete alalt', Nonaginta, Eesti NSV Teaduste Akadeemia Emakeele Seltsi Toimetised 6 (Tallinn, 1963), p. 107.

5. Only the following combinations are contrastive in monosyllabic words: 1 + 3, 3 + 1, and 3 + 3. The combinations 2 + 3 and 3 + 2 do not occur at all; the combination 2 + 2 may occur in words of more than one syllable. In other words, vowel quantities 2 and 3 are not contrastive before consonant quantity 3, nor are consonant quantities 2 and 3 contrastive after vowel quantity 3. It is not immediately obvious whether the characteristic features of 'overlength' are associated with the vowel or the consonant. The author doubts whether it is possible to identify 'the location of the perceived accentual peak' in such words. (For the opposite assumption, cf. Tiit-Rein Viitso, 'Üks lingvistiline ahelprobleem', Nonaginta, Eesti NSV Teaduste Akadeemia Emakeele Seltsi Toimetised 6 (Tallinn, 1963), pp. 276-278.)

6. An excellent summary of the techniques of acoustic phonetics is contained in the article by C. Gunnar M. Fant, 'Modern Instruments and Methods for Acoustic Studies of Speech', Proceedings of the Eighth International Congress of Linguists (Oslo, 1958), pp. 282-358. For a description of the identification of segment boundaries, cf. also G. E. Peterson and I. Lehiste, 'Duration of Syllable Nuclei in English', Journal of the Acoustical Society of America 32 (1962), pp. 693-703.

7. It is assumed that in consonant clusters the last consonant either starts the following syllable or contains a syllable boundary. Although the placement of the syllable boundary seems to be largely automatic and syllables might therefore be denied independent phonological status, there exist nevertheless some instances in which a syllable boundary is not associated with an intervocalic consonant: avaus has the same syllabic structure as kavalus. It is therefore necessary to indicate syllable boundaries in a phonemic transcription. The problem will be considered below in greater detail. The phonemic status of syllable boundaries is also discussed by Valmen Hallap in 'Fonoloogiline etüüd eesti keele väldete alalt', pp. 117-121, and by Tiit-Rein Viitso in 'Teese ja antiteese', Emakeele Seltsi Aastaraamat 9 (Tallinn, 1963), pp. 11-14.

8. The question of degrees of sentence stress in Estonian has not been satisfactorily solved. Presence of primary stress and presence and placement of secondary stress are considered an essential part of the word structure in Estonian; but no unambiguous system for determining the degrees of sentence stress

has been proposed. R. T. Harms states (Estonian Grammar, p. 162) that a minimum of five phonetic stresses must be accounted for; he does not specify, however, what the criteria are for recognizing the five stresses. The author recognizes primary, secondary, and weak stress at the word level. At the sentence level, the syllable with primary stress may receive an additional amount of emphasis or may lose its independent word stress, replacing the primary stress by secondary stress. There is, at the moment, no way to measure the relative degree of sentence stress. Some morphological clues to the absence of sentence stress may be found, such as the selection of the short forms of the personal pronouns ma, sa, ta, me, te, nad instead of mina, sina, tema, meie, teie, nemad. However, there are instances in which a short form may be restressed, and others, in which a long form is subjectively felt to be unstressed.

9. In the case of /p/, the placement of the syllable boundary could not be associated with any observable feature on a spectrogram. Compare, however, the analogous case of kooki (458), reproduced on Figure 6.

10. There are only very few words beginning with /p/ that may function as clitics of some sort, appearing completely unstressed within the sentence. One of these is the word pole, which is normally less stressed than the equivalent ei ole. It is worth recalling that the form pole is itself the result of a fusion of an older ep ole, in which the final consonant of ep has been carried over to form the initial consonant of the form pole. Nevertheless, pole constituted only one of the six unstressed cases. The full list included suu pääle (19), tema pole (21), hooplemata peaks (64), sõela panid (128), pildile pandi (468), and niipea (482).

11. Words of the type are discussed in 'Compounding as a Phonological Process' (cf. footnote 3). The problem of the assignment of such non-contrastively long consonants to either quantity 2 or quantity 3 is discussed in chapter 7.

12. Cf. 'Segmental and Syllabic Quantity in Estonian', p. 38.

13. As was mentioned above, systematic data about vowel duration in these utterances are not yet available. However, the average duration of the vowels and diphthongs preceding this allophone of /t/ was calculated and found to be 14.2 csec. The duration of /a/ in such a word as saata (382) was 15 csec, which may be compared directly with the duration of /a/ in saada (381), which was 20 csec. The material contained only one word in which a vowel in quantity 2 was followed by /t/ in quantity 2: the word jääte (486), in which the durations of /ä/ and /t/ were 6 and 5.5 csec respectively. While the average durations of the vowels and /t/ in words such as saata were longer than corresponding sounds in quantity 2 (in the combination 2 + 2 as well as in combinations of 2 + 1 for the vowel and 1 + 2 for the consonant), they

were nevertheless considerably shorter than either in the combination 1 + 3 or 3 + 1.

14. The problem of rearticulation is discussed in 'Acoustic Studies of Boundary Signals' (cf. footnote 3), pp. 178-179, where some evidence is presented for an assumed underlying physiological process. The spike observed within certain rearticulated plosives is quite similar to spikes observed within clusters of plosives whose members are produced with a differing articulatory process. There are some instances in which no spike can be detected within the gap corresponding to a cluster of unlike plosives; in the case of geminates, the spike is present in a minority of instances, but frequently enough to make it unlikely that the feature is an instrumental artifact. In the course of a previous study of the speech of four other informants, similar spikes were occasionally observed (cf. 'Segmental and Syllabic Quantity in Estonian', p. 52 and footnotes 18, 42, and 43); thus the rearticulation of the plosives in quantities 2 and 3 is not a peculiarity of the speech of the author. More data are clearly necessary to judge the generality of the phenomenon.

15. The average duration of the vowels in these words was 15.8 csec. For example, the duration of /o/ in kooki (458) was 15 csec, while the duration of /a/ in saagi (12) was 20 csec. The durations of overlong vowels before /t/ in the words saata (382) and saada (381) were likewise 15 and 20 csec respectively (cf. footnote 13).

16. Cf. the chapter on sandhi in Paul Ariste's book Eesti keele foneetika (Taliinn, 1953), pp. 71-74. The interpretation of sandhi phenomena as a manifestation of the subordination of lower-level phonological units to units at a higher level of the phonological hierarchy is considered in my report on Juncture, to be published in the Proceedings of the Fifth Congress of Phonetic Sciences, Münster 1964 (A. S. Karger & Co., Basel), in press.

17. The argument might conceivably also be stated as follows: before a consonant in quantity 3, the vowel may either be in quantity 1 or in a non-contrastively long quantity. The data reported in this paper concern consonant quantity; a study of the durations of the vowels in the sequences discussed above would provide essential supplementary material to complete the description.

18. In this set of data, the average duration of 15 occurrences of /t/ in such words as saata was 12.4 csec; the average duration of /t/ in 39 occurrences of such words as huvitav was 12.1 csec. The comparable values for /k/ were 13.4 and 12.7 csec, respectively. Compare also the spikes in kooki (458), Figure 6, and huvitav (498), Figure 7.

19. In 19 occurrences of words such as lainetab (97) /t/ had an average duration of 11.7 csec, while in 20 occurrences of words like huvitav /t/ had an average duration of 12.4 csec.

20. Cf. Tiit-Rein Viitso, 'Tüvelisest astmevaheldusest (eriti eesti keeles)', Emakeele Seltsi Aastaraamat 8 (Tallinn, 1962), pp. 44-62, especially p. 55, where Viitso states that quantity 3 is conditioned by the presence of a relatively strong accent; Robert T. Harms, Estonian Grammar, p. 12 and passim; and Valmen Hallap, 'Fonoloogiline etüüd eesti keele väldete alalt', p. 103 and passim.

21. It should also be kept in mind that the vowel in saata is shorter than in such words as saada (cf. footnote 13). It appears difficult to associate 'overlength' with a vowel whose duration actually falls close to the range of vowels in quantity 2.

22. In words such as aastate, whose first syllable is overlong, the average duration of the allophone of /t/ between the second and third syllable was 8.8 csec. The average duration of allophones of /t/ in intervocalic quantity 2 (between the first and second syllable) was 8.3 csec. After a disyllabic sequence whose first syllable is in syllabic quantity 3, the allophone of /t/ thus had a duration that was much closer to intervocalic quantity 2 than to the ambiguous quantity observed in saata and huvitav (12.1 csec).

23. It is unfortunately not possible to develop this suggestion fully within the limits of this paper, Cf., however, my 'The Function of Quantity in the Phonological Systems of Finnish and Estonian', in press.

24. I speak a variety of standard Estonian which is based on the pronunciation of Tallinn. In my usage the syllabification rule seems to apply without exception. I became especially aware of it studying this set of spectrograms. For example, I normally pronounce word-initial /h/ wherever it is required by the literary standard; but in the sequence hiir hüppas (276), reproduced on Figure 4, I discovered that I had omitted the /h/ and in fact produced a syllable-initial sequence /rü/. Contrastive placement of the syllable boundary before and after the intervocalic consonant has been claimed for such sequences as tema lelu vs. temal elu by Valmen Hallap in 'Soome-ugri transkriptsioon ja fonoloogiline transkriptsioon', ENSV Teaduste Akadeemia Keele ja Kirjanduse Instituudi Uurimused 6 (Tallinn, 1961), p. 223; however, in the same article Hallap describes a Southern Estonian feature in his own speech, and it is therefore not impossible that the contrastive placement of syllable boundary which Hallap has observed in his speech may be a Southern Estonian feature. Observations concerning the validity of a similar syllabification rule in certain dialects and its absence in others have been made with regard to Finnish. Cf. Terho Itkonen, Proto-Finnic Final Consonants (Helsinki, 1964), p. 262 and elsewhere.

25. 'Segmental and Syllabic Quantity in Estonian', p. 55.

26. This statement applies to overlong consonants and consonant clusters following short vowels. The number of consonant

clusters following long vowels was too small in this set of data to make any comparison meaningful. The actual measured durations, averaged from Table I, were as follows: intervocalic consonant in quantity 3 (after short vowel), 22.6 csec; syllable-final overlong consonant (i. e. overlong consonant as first member of a cluster of two consonants), 14.1 csec; syllable-initial consonant in quantity 1 (second member of a cluster of two consonants), 5.4 csec. The total of the last two instances is 19.5 csec, which is only slightly — and probably nonsignificantly — shorter than the average duration of consonants in intervocalic quantity 3.

27. In this set of data, the duration of utterance-final plosives in quantity 3 after vowels in quantity 1 was, on the average, 28.2 csec. The comparable duration of syllable-final overlong /t/ and /k/ was 12.5 csec. The utterance-final position may have influenced the duration of the final plosives, but the difference in the durations is obviously greater than can be accounted for by normal positional conditioning. Only utterance-final consonants in quantity 3 could be used for comparison, since in cases where a word-final consonant was followed by a word beginning with a vowel, the syllable boundary was placed within the word-final consonant.

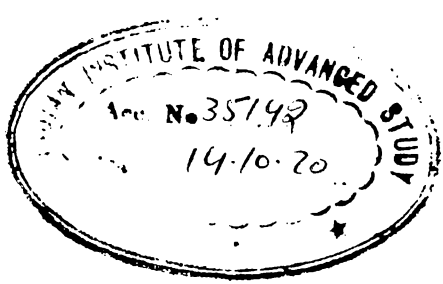
28. 'Segmental and Syllabic Quantity in Estonian', p. 53.

29. Valmen Hallap has recently claimed that the cluster /kt/ may indeed occur in three contrastive quantities in Estonian, paralleling the three quantities of the cluster /tr/ in such words as nõdra, nitro (as in nitroglütseriin) and nõtra. The examples quoted for clusters of plosive + plosive in a duration similar to that of /tr/ in nõdra are ragbi (the game rugby, which is barely known in Estonia) and sogdi (name of a language). The solution offered by Hallap is the establishment of a special juncture phoneme, /ˌ/, which occurs before the /tr/ cluster in nõdra and before the /kp/ cluster in ragbi. The placement of this juncture phoneme need not coincide with a syllable boundary. ('Fonoloogiline etüüd eesti keele väldete alalt', pp. 118-119.) I find this solution unacceptable on two grounds. Within the linguistic theory in which phonological units form an ascending hierarchy, junctures constitute phonetically manifested boundaries between phonological units, and their occurrence depends upon the presence of those units (cf. my paper on 'Juncture' referred to in footnote 16). Alternatively, junctures have been identified with the boundaries of grammatical (morphological-lexical) units. Within this theory, not all grammatical boundaries need to have phonetic manifestation, but phonetically manifested boundaries may occur only at points in the sequence which are simultaneously boundaries of grammatical units (Morris Halle, The Sound Pattern of Russian, 's-Gravenhage 1959, p. 19). The establishment of junctures as segmental phonemes, occurring at points within a sequence that have no correlation to the presence of boundaries of either phonological or grammatical units, appears to be a highly

artificial, ad hoc solution. I also doubt whether rare loanwords and words belonging to a highly specialized vocabulary such as sogdi and ragbi can be used as a basis for the phonological analysis of a language. (Cf. Mati Hint, 'Fonoloogilistest võõrjoontest normeeritud eesti kirjakeeles', Emakeele Seltsi Aastaraamat 10 (Tallinn, 1964), pp. 25-43.)

30. There are some exceptions to this rule. Words such as avaus have the same syllabic structure as such words as kavalus; the syllable boundary falls between /a/ and /u/ in the first word. Such sequences are also possible at the boundaries of words ending and beginning with vowels. The phonetic realization of the syllable boundaries and word boundaries in such sequences is a problem which I hope to consider separately. In view of the basic role which syllables appear to play in Estonian phonology, I find myself in sympathy with the proposal of Tiit-Rein Viitso to define syllable boundaries as consonantal phonemes occurring in syllable-initial position before the syllable nucleus in such cases when the syllable does not begin with a contoid. Cf. Tiit-Rein Viitso, 'Teese ja antiteese', pp. 13-14. However, I cannot agree with the placement of the /, / phoneme in positions where it does not coincide with a syllable boundary for the sole aim of facilitating a linear phonemic transcription.

31. The results of the analysis of the durations of the vowels occuring in this set of 500 sentences are discussed in my paper 'Vowel Quantity in Word and Utterance in Estonian', presented at the Second International Congress of Finno-Ugricists, Helsinki, 1965.



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