

Variability in the Production of Suprasegmental Patterns

Ilse Lehiste

This paper is an exploratory study of variability in the production of suprasegmental patterns. It has been observed before that in repeated productions of test words containing sounds whose duration is linguistically contrastive, native speakers are capable of great regularity in producing these repetitions. In one such study, Nootboom (1972) observed regularities both in the production of spoken utterances and in adjusting the durations of synthetic segments to match an internal standard. His speakers produced Dutch nonsense words with long and short vowels, achieving standard deviations ranging from 2.3 to 9 msec. In adjusting the durations of synthetic vowels to produce words with phonemically long and short vowels, Nootboom's subjects showed similar accuracy: standard deviations ranged from 1.7 msec for short vowels and 4 msec for long vowels (for the best subject) to 7 msec for short vowels and 9 msec for long vowels.

In Nootboom's studies, it was the vowel whose duration was contrastive. In the present study, I investigated disyllabic Estonian words in which either the duration of the first vowel or the duration of the intervocalic consonant was contrastive, as well as words in which the duration of the first vowel co-varies with that of the intervocalic consonant. The question is then to what extent the fact that both the durations of the vowel and the consonant are contrastive may influence their variability. A second question introduced in this study concerns the importance of nativeness in the extent of variability.

In an earlier study (Lehiste, Morton and Tatham, 1973) we had investigated the production of intervocalic consonants in Estonian words like taba-tapa - tappa by one native and one non-native speaker. The study revealed that, as far as may be generalized from a single speaker, native speakers produce intervocalic consonants with syllabification patterns that differ from those by non-native speakers. Syllabification patterns are intimately involved in the production of contrastive quantity in intervocalic consonants: the difference between short and long geminates depends on the placement of the syllable boundary. It might be expected, then, that it is relatively more difficult for non-native speakers to produce contrasts in the duration of intervocalic consonants than in vowels. One might thus expect that, first of all, the productions of non-native speakers will show greater variability than those of native speakers, and further, that the difference in variability will be greatest in the production of intervocalic short and long geminates.

The present study addresses itself to both questions. A set of seven Estonian words constitutes the test materials. The quantity structure of the seven words is shown in Figure 1. The words included in the set are listed and glossed below the figure.

Duration of consonant	Duration of vowel		
	1	2	3
1	kodi	koodi (2)	koodi (3)
2	koti	gooti	
3	kotti		kooti

kodi - 2. sg. imperative of the verb kodima 'to roam around'

koodi (2) - gen. sg. of the (loan) word kood 'code'.

koodi (3) - part. sg. of the (loan) word kood 'code'

koti - gen. sg. of the noun kott 'sack'

kotti - part. sg. of the noun kott 'sack'

gooti - uninflected adjective, 'Gothic' (loanword)

kooti - part. sg. of the noun koot 'flail'

Fig. 1. Quantity structure of seven Estonian words.

While three words included in the set are loanwords, all are completely integrated into the phonological system. The word gooti is pronounced with an initial voiceless plosive.

Phonemically, the seven words consist of the same segmental sounds: /k/, /o/, /t/, and /i/. They differ in the quantity of the vowel /o/ and the intervocalic consonant /t/. In the set kodi - koodi (2) - koodi (3), the intervocalic consonant remains in quantity 1 (short), while the vowel /o/ changes from quantity 1 in kodi to quantity 2 (long) in koodi (gen.) to quantity 3 (overlong) in koodi (part.). In the kodi-koti-kotti set, the vowel /o/ remains in quantity 1, while the intervocalic consonant varies from quantity 1 in kodi to quantity 2 in koti and quantity 3 in kotti. In the kodi - gooti - kooti set, both the vowel /o/ and the intervocalic consonant vary from quantity 1 in kodi to quantity 2 in gooti and quantity 3 in kooti. As the figure shows, two combinations are not represented; quantity 2 does not combine with quantity 3 in either direction.

The words were produced by two speakers, one native (IL), the other non-native (LS). LS had been a student of IL for several years; her pronunciation of Estonian appeared to IL (and to several other native speakers) quite acceptable in isolated repetitions and adequate in longer spontaneous utterances. All the systematic instruction LS had received in Estonian had been given by IL, so from the very beginning the pronunciation of IL had served as a model for LS. Both speakers produced about 10-12 tokens of each word. IL read the words

from a list, repeating each word about ten times before going on to the next word. The words were read in the order kodi - gooti - kooti - koodi (2) - koodi (3) - koti - kotti. LS followed the same procedure; she made the recording by herself, without having heard IL's productions. The recordings were made in an anechoic chamber at the Linguistic Research Laboratory of the Ohio State University, using high-quality equipment.

The tapes were processed through a Frøkjaer-Jensen trans-pitch meter and intensity meter and displayed on a Mingograf operated at a speed of 10 cm/sec. Duration measurements were made using generally known techniques. The duplex oscillogram produced by the experimental setup served as the primary basis for segmentation.

Table 1 shows average durations and standard deviations of segments in this set of seven Estonian words, produced by the two speakers.

TABLE 1

Average durations and standard deviations of segments in a set of seven Estonian words, produced by two informants (N = 10); durations in milliseconds.

Word	Speaker IL						
	/o/		/t/		/i/		
	Dur.	SD	Dur.	SD	Dur.	SD	
kodi	167.2	10.1	83.2	5.5	228.5	19.4	
koodi (2)	253.5	14.3	73.2	6.1	192.0	16.4	
koodi (3)	330.7	15.1	82.9	7.8	167.6	19.0	
koti	161.3	7.6	211.5	15.8	214.2	19.2	
kotti	151.8	4.5	475.0	29.3	172.9	13.3	
gooti	205.7	12.2	177.7	10.1	188.6	29.4	
kooti	225.9	13.3	298.9	30.8	172.7	25.4	
			Speaker LS				
kodi	104.8	26.2	55.5	8.3	250.8	16.6	
koodi (2)	176.2	19.3	78.8	12.1	204.9	20.2	
koodi (3)	318.5	21.5	83.0	5.3	116.7	17.1	
koti	105.8	14.7	229.0	21.1	290.2	16.3	
kotti	120.1	13.7	342.4	43.5	239.3	21.4	
gooti	246.9	23.0	152.3	35.3	183.9	22.7	
kooti	322.7	22.8	228.2	70.4	151.7	21.9	

Table 2 gives the overall word length for the two speakers.

TABLE 2

Average overall word length in a set of seven Estonian words produced by two informants (N = 10).  
Values in milliseconds.

Word	Speaker IL	Speaker LS
kodi	478.9	411.1
koodi (2)	518.7	459.9
koodi (3)	581.2	518.2
koti	587.0	625.0
kotti	799.7	701.8
gooti	572.0	583.1
kooti	697.5	702.6

Figure 2 is a graphic representation of the average durations of segments, showing at the same time the average durations of the seven test words. A casual inspection of the figure leaves the impression that the two speakers were producing essentially the same patterns.

Figures 3, 4, and 5 show graphically the differences in standard deviations between the two speakers. Figure 3 (p. 173) displays the words in which the vowel duration was contrastive. It appears that IL (the native speaker) had somewhat smaller variability in the duration of the first vowel and occasionally greater variability in the duration of the second vowel; the variability in the duration of the intervocalic consonant was about equal for the two speakers. Figure 4 (p. 174) shows again less variability for the native speaker in the two contrastive segments--the vowel of the first syllable and the intervocalic consonant, while the duration of the second vowel shows less variability for the non-native speaker. It is in the productions of words from the third set, shown on Figure 5 (p. 175), that the difference in variability between the two speakers becomes really apparent. The native speaker has considerably less variability in the duration of the first vowel and the intervocalic consonant, while the non-native speaker has less variability in the final vowel in all three words.

Both starting hypotheses appear to be confirmed: the native speaker shows less variability in the production of phonemically contrastive durations than the non-native speaker, and it is in the production of intervocalic geminate consonants (/t/ in quantities 2 and 3) where the difference between native and non-native variability is greatest.

The absolute values of the standard deviations vary with the length of the contrastive segment. For a comparison with the Dutch data, it might be pointed out that the standard deviation for the native speaker (IL) in the production of short vowels was between 4.5 msec in kotti and 10.1 msec in kodi. For the long and overlong vowels, the standard deviations were greater, ranging from 12.2 msec in gooti to 15.1 msec in koodi (3). A better measure of variability might be provided by the use of a statistic called relative variance, which for this paper

is defined as  $s^2/m$  (variance divided by the mean) (Allen, 1973). Table 3 gives the relative variance for the segments /o/, /t/ and /i/ in the productions of the seven words by the two informants.

TABLE 3

Relative variances ( $\frac{s^2}{M}$ ) of segments in a set of seven Estonian words, produced by two informants (N = 10). Values in msec<sup>2</sup>/msec.

Word	Speaker IL			Speaker LS		
	/o/	/t/	/i/	/o/	/t/	/i/
kodi	.605	.363	1.656	6.568	1.230	1.099
koodi (2)	.811	.516	1.394	2.104	1.873	1.999
koodi (3)	.688	.732	2.164	1.450	.344	2.499
koti	.360	1.174	1.716	2.027	1.940	.911
kotti	.135	1.801	1.018	1.555	5.511	1.916
gooti	.721	.571	4.570	2.144	8.203	2.795
kooti	.788	3.177	3.742	1.606	21.714	3.158

The variability in the duration of vowels and consonants with different degrees of quantity appears less great when mean durations of the segments are taken into account. However, the use of relative variance helps bring out additional differences between the speakers. In the productions of IL, greatest variability both in absolute and relative terms was observed in the duration of the final vowel, which is not independently contrastive in Estonian. In the productions of the non-native speaker (LS), the variability in the intervocalic geminates is particularly prominent, while variability in the productions of the non-contrastive final vowel is in fact smaller than in productions by the native speaker. Table 4 shows the differences in relative variances of productions of segments by the two speakers.

TABLE 4

Relative variance ( $\frac{s^2}{M}$ ) differences between productions of segments in a set of seven Estonian words produced by two informants (LS - IL). Values in msec<sup>2</sup>/msec.

Word	/o/	/t/	/i/
kodi	5.963	.867	-.557
koodi (2)	1.293	1.357	.605
koodi (3)	.762	-.388	.335
koti	1.667	.766	-.805
kotti	1.420	3.710	.898
gooti	1.423	7.632	-1.775
kooti	.818	18.537	-.584

The values in the table represent the result of subtracting the relative variances of IL's productions from those of LS. Negative values indicate instances in which IL had greater variability than LS. If the values presented in Table 4 can be considered indices of nativeness, then it is indeed true that the productions of the non-native speaker differ from those of the native speaker mainly in the production of intervocalic geminate consonants. A further point emerges from this table: the relatively great variability of /o/ in the word kodi, produced by LS. The difference in relative variances is here noticeably greater than the difference in standard deviations. Control of the duration of the vowel in a short open syllable is evidently much more difficult to achieve for a non-native speaker than, for example, control of an overlong vowel. This may be attributed to the influence of English, which constitutes the substratum for LS. In English, there are no stressed open syllables ending in a short vowel.

It should be emphasized that the two subjects do not appear to differ in phonetic ability, which is indicated by the fact that speaker LS produced her final vowels with considerably less variability than IL. I believe this difference to be due to the fact that for IL, the duration of /i/ is not an independent variable and therefore not under the same kind of control as the durations of /o/ and /t/. For LS, it may well be that all three durations are subject to the same kind of control. This may be deduced from the fact that in her productions, the variability of all three segments is of the same order of magnitude. The difference between the two speakers is due to a more precise control of the durations of contrastive segments by the native speaker.

It was hypothesized at the beginning of this paper that a difference between native and non-native speakers might appear in the variability with which they produce repeated utterances containing segments whose duration is linguistically contrastive. It was hypothesized further that for Estonian, special difficulties might arise for non-native speakers in the production of intervocalic geminate consonants, and that these difficulties might be reflected in increased variability. Both hypotheses were confirmed. It is hoped that the results of this exploratory study may be validated by analyzing the speech of a considerably larger number of informants. More generally, the present study might serve as a basis for future investigation of suprasegmental foreign accents.

#### References

- Allen, G. D. 1973. Segmental timing control in speech production. *Journal of Phonetics* 1.219-237.
- Lehiste, Ilse. 1970. *Suprasegmentals*. Cambridge, Mass.: M.I.T. Press.
- Lehiste, Ilse, Katherine Morton, and M. A. A. Tatham. 1973. An instrumental study of consonant gemination. *Journal of Phonetics* 1.131-148.
- Nooteboom, S. G. 1972. *Production and Perception of Vowel Duration: A study of the durational properties of vowels in Dutch*. Dissertation, University of Utrecht.

IL

LS

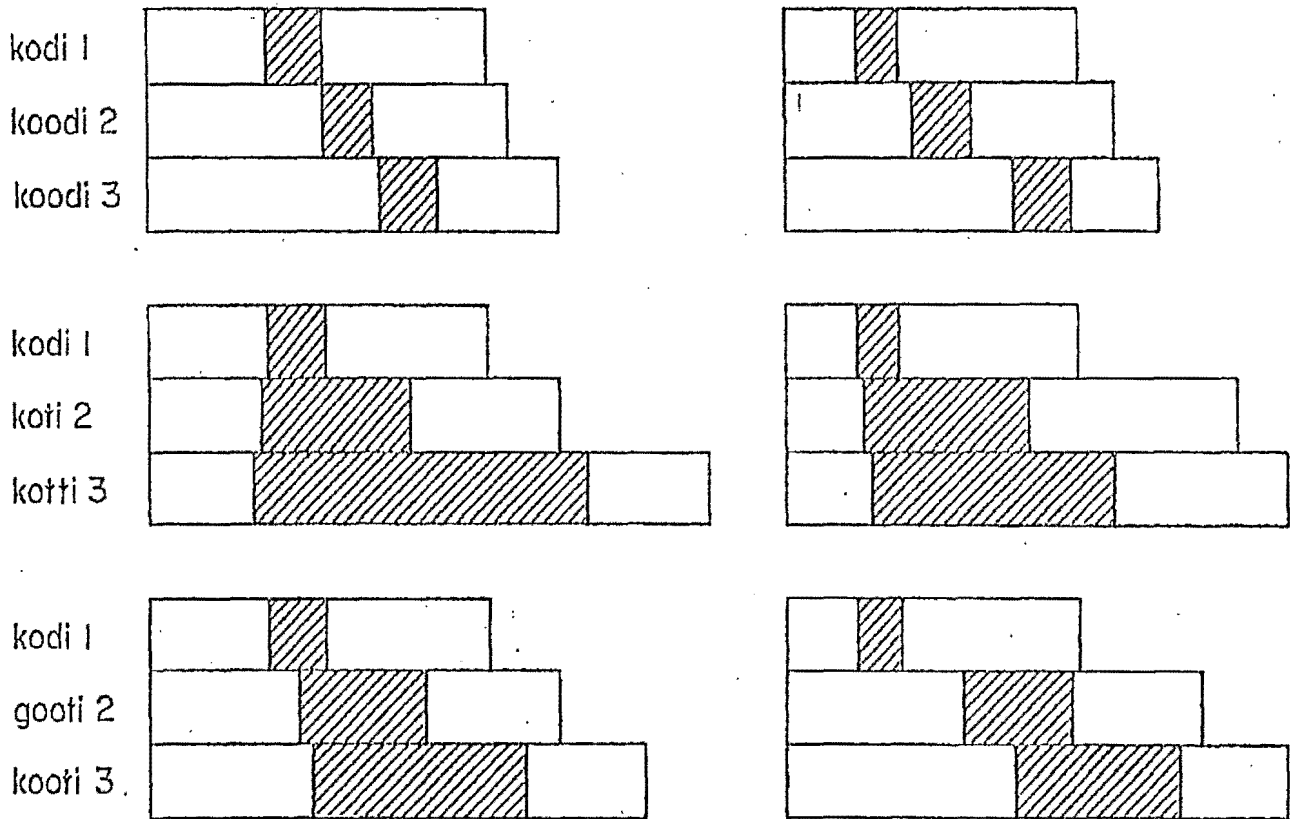


Fig. 2. Average durations of segments in seven Estonian words.

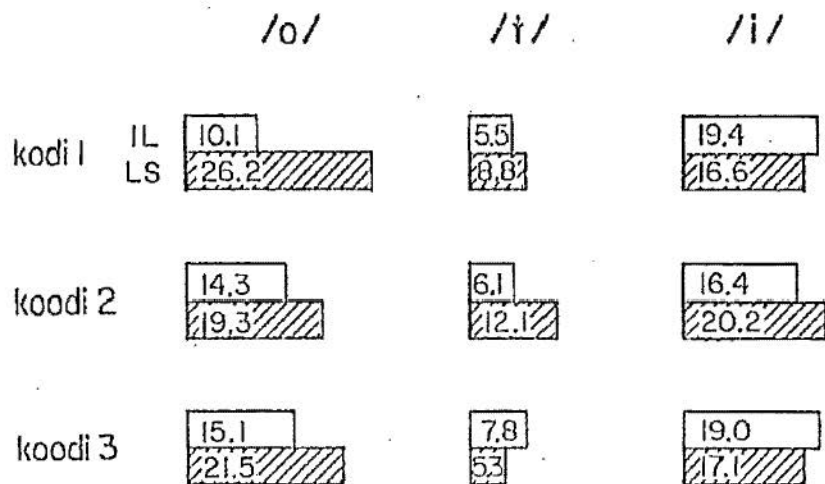


Fig. 3. Standard deviations in productions of three words.



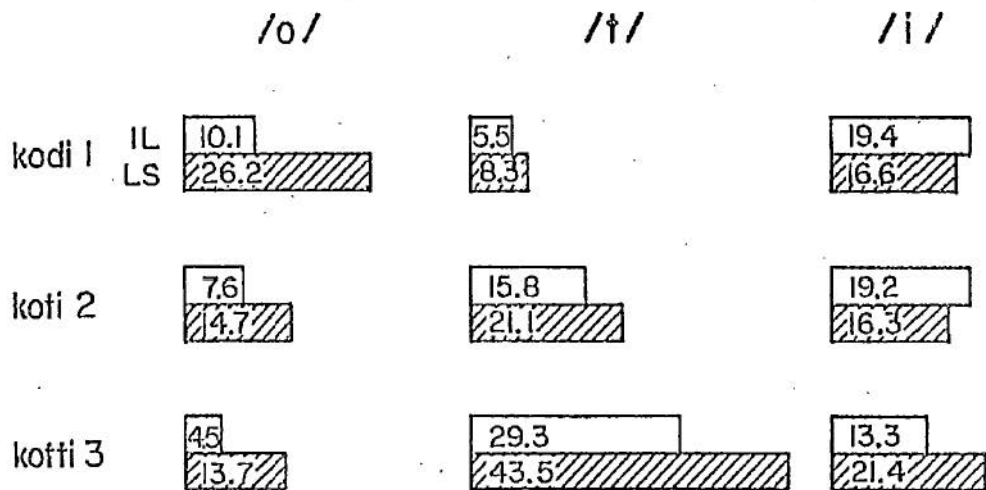


Fig. 4. Standard deviations in productions of three words.

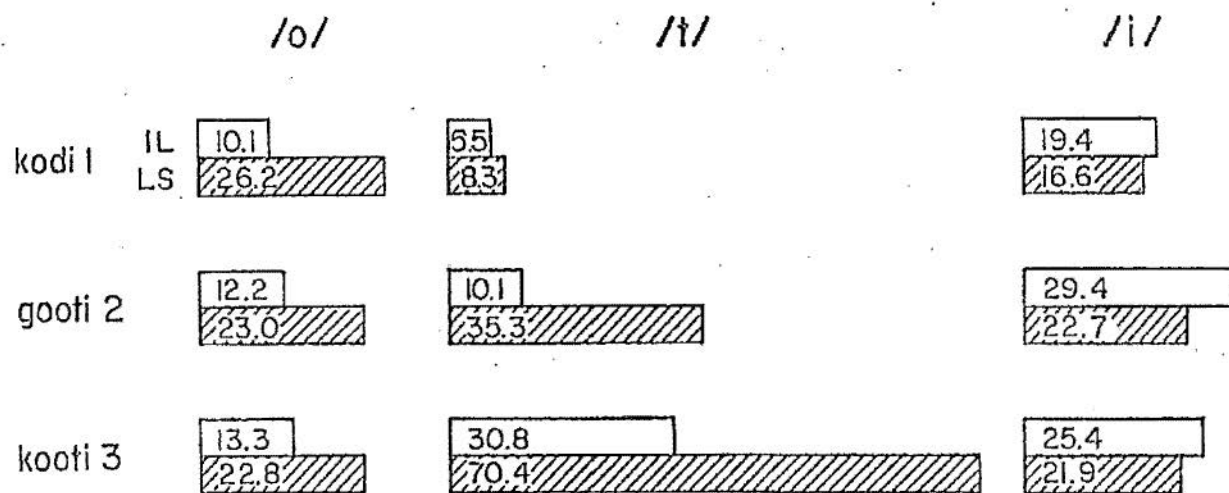


Fig. 5. Standard deviations in productions of three words.