

## OBSERVATIONS ON THE DURATION OF /s/ IN STANDARD SWEDISH

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**ABSTRACT** - From a large investigation of the temporal structure and variations of consonants in clusters in Standard Swedish, the alveolar voiceless fricative /s/ was selected for this presentation. Ten speakers produced /s/ as a singleton and as a member of consonant clusters in a frame sentence under different conditions. These included prominence (focus accent), cluster structure, position in the word, and preceding phonological vowel length. Focus accent has the most pronounced effect on segment duration increasing it by about 40 ms in all conditions. The results are compared to some earlier findings for Swedish and American English.

### INTRODUCTION

Research is currently being undertaken in Umeå in order to investigate the phonological and phonetic qualities of consonants and consonant clusters in Standard-Swedish. Special interest is being devoted to (1) the phonological processes that affect consonants and (2) the temporal structure and variation of consonants as singletons and members of clusters. A large amount of data has been collected from five male and five female speakers of Standard Swedish. Each produced 62 test words, with and without focus accent, in phonetically controlled sentences five times, and 30 minutes of spontaneous speech.

The temporal behaviour of Swedish single segments has been studied extensively. Eiert (1964) measured the durations of stressed long and short vowels and the following consonant. A model for calculating vowel durations has been proposed by Lindblom et al. (1976). It takes into account different variables, for instance, position in the word and phrase and number of preceding and following syllables. The present study extends the earlier research by including focus accent and spontaneous speech. This permits more accurate description of consonant clusters in Standard Swedish for a number of variables. Our work is interesting for several reasons. The results will fill a gap in our phonetic and phonological knowledge of Swedish. They will also be valuable for typological studies in a universal and contrastive perspective. This is especially true of aspects of phonotactic structure and prosodic features that interact with consonants and consonant clusters.

In his work on a generative theory of segmental duration in English, Klatt (1974), for the sake of illustration of his point, selected the consonant /s/ in order to demonstrate several important issues. It is well known that timing and temporal structure of segments constitutes a central feature in the phonological system of languages including segments and prosody. Klatt enumerates a long list of conditions that affect the durational value of segments. Without repeating them here, our main concern is on the effect of focus accent on consonant durations under several conditions. Parallel to Klatt's approach and for reasons of comparison, the same consonant /s/ in Swedish was selected for investigation. Being one of the alveolar consonants, it is one of the most frequent ones and shows a rather unrestricted distribution. It forms consonant clusters of different types in all word positions. In initial three-consonant clusters, e.g. /spl-, str-, skv-/ it is comparable to English and German, the only permissible first consonant (cf. Eiert 1970, p. 100 who refers to Melin 1927-29) in this position. It is also well known from research on English and Swedish that the duration of consonants decreases when they form part of a consonant cluster (cf. for instance Lindblom and Rapp 1973, Klatt 1974). Swedish durational rules derived from a sentence data base were formulated by Carlsson and Granström (1986). These are similar to the rules expressed by Klatt for American English. The Swedish data base consisted of 150 Swedish sentences, containing about 5000 phonemes, read by one male speaker. The prosodic condition of focus accent, however, was not varied.

## CURRENT INVESTIGATION

The aim of the present study is to investigate the effects of the following factors on the duration of /s/-segment:

- (1) Prominence (focal and non-focal accent)
- (2) Cluster structure (single segment, member of two- and three-segment clusters)
- (3) Position in the word (word-initial and word-final)
- (4) Phonological length of the preceding vowel (long and short).

## METHOD

### Target words

In this paper, only part of the phonetically controlled material of the research project is presented. Fourteen monosyllabic real Swedish words, shown in Table 1, a subset of the 62 target words in the entire study, were selected for this presentation. Words were selected which had the target /s/ segment as single consonant and as member of two- and three-segment clusters. Single /s/-segment occurs in word initial and word final position. The word initial two-segment clusters are /sp, st, sk, sn, sl/, and the word initial three-segment clusters are /spr, str, skr/. The two-segment clusters /sp, st, sk/ also appear in word final position. In this position, three-consonant clusters are not permitted in Swedish. All words, except *fas*, contain the short stressed vowel /a/. Word final /s/-segment follows either the phonologically short [a] vowel in *kass* or the phonologically long [ɑ:] vowel in *fas*.

	SINGLE SEGMENT	MEMBER OF TWO-SEGMENT CLUSTER	MEMBER OF THREE-SEGMENT CLUSTER
WORD-INITIAL POSITION	satt ( <i>stocky</i> )	spann ( <i>span</i> ) stam ( <i>stem</i> ) skatt ( <i>treasure</i> ) snack ( <i>chat</i> ) sladd ( <i>flex</i> )	spratt ( <i>trick</i> ) straff ( <i>punishment</i> ) skratt ( <i>laughter</i> )
WORD-FINAL POSITION	kass ( <i>scrap</i> ) fas ( <i>phase</i> )	hasp ( <i>hasp</i> ) kast ( <i>throw</i> ) mask ( <i>worm</i> )	—

Table 1. The target monosyllabic words used in the investigation.

A minimal dialogue containing a question and the appropriate response was developed to accommodate the target words that were pronounced either with focal accent or without focal accent. Focal accent on the test word was elicited by the question "Vad sa du i går?" (*What did you say yesterday?*). Non-focal accent was elicited by the question "När sa du \_\_\_\_?" (*When did you say \_\_\_\_?*). Both questions resulted in the same carrier sentence "Jag sa \_\_\_\_ i går." (*I said \_\_\_\_ yesterday*), in which the focal accent fell either on the target word or the word "i går" (*yesterday*).

### Subjects

Ten subjects, five male and five female university students, around the age of 25 years, all native speakers of Standard-Swedish participated in the investigation.

### Procedure

Recordings were made of each subject producing the full set of randomised dialogues with an experimenter in a sound attenuated room. For each target word the experimenter introduced the dialogue with a question which elicited the subject's response. Subjects were encouraged to speak at their usual speaking rate as if participating in a natural conversation. A total of 1 400 (10 subjects x 14 words x 2 levels of prominence x 5 repetitions) items were produced.

## Measurements

The recordings were stored and labelled as sound files using ESPS/waves+™. An oscillogram was made for each word, and the duration of /s/-segment was measured between the onset and offset of the /s/-frication.

## RESULTS AND DISCUSSION

Measurements were analysed to investigate the effect of (1) prominence, (2) cluster structure, (3) position in the word, and (4) preceding phonological vowel length. Results are presented in Figures 1 and 2 and Tables 2 and 3 below.

### Prominence

A three-way analysis of variance (prominence x cluster structure x position in the word) was calculated for the duration of the /s/. The word *kass*, which only is used in comparison with the word *fas* investigating the effect of the preceding vowel's phonological length, was excluded from this analysis.

The duration of /s/-frication in words with focal accent (+ focus) and without focal accent (-focus) across the different cluster structures (s, sC, sCC) and different positions in the word (initial, final) is shown in Figure 1. The numbers of observations is: s\_, \_s: n = 100; \_sC, \_sCC; n = 300; sC\_: n = 500. A reliable difference in /s/ duration ( $F=319.5$ ;  $p<.001$ ) was observed between focal and non-focal accent. The duration of /s/ in words without focal accent is shorter ( $\mu=98$  ms) than in words with focal accent ( $\mu=141$  ms). The difference between the /s/ duration in focused words and non-focused words is 43 ms. No interactions between the prominence level, cluster structure and position in the word were found.

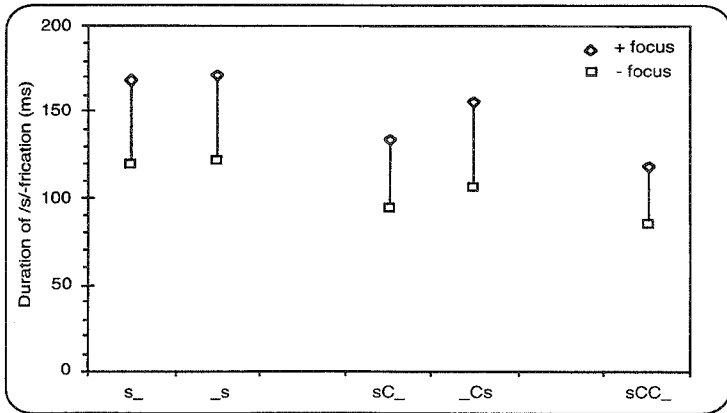


Figure 1. The duration of /s/-frication in words with focal accent (+ focus) and without focal accent (-focus) across the different cluster structures (s, sC, sCC) and initial/final positions in the word.

These findings confirm results from earlier investigations. Czizler (1993) found a lengthening effect of focal accent on the duration by 39 ms for single consonant segments (/s/, /t/, /k/) and consonant sequences (/st/, /kt/, /kst/) in word medial position. Similar observations were made by Bannert (1979). Studying the effect of focus accent on quantity with two speakers of Standard Swedish has shown that focus accent lengthened the duration of the stressed vowel and the following consonant considerably. The lengthening of the two segments of the VC-sequence caused by focus accent is concomitant with the signalling of focus accent in Standard Swedish be a separate F0-rise (Bruce 1977).

For American English, Klatt (1974) noticed a slight tendency for /s/ to be somewhat shorter preceding vowels with secondary stress compared to primary stress. Although in our material the /s/ appeared in words with or without focus accent, and thus is not comparable to Klatt's distinction between primary and secondary stress within words, in both cases the prominence dimension is concerned. For the American English data the small difference in duration parallels the small difference in degree of prominence between primary and secondary stress. The Swedish data, however, show a large difference in duration that parallels the large difference in degree of prominence between focus and non-focus accent.

#### Cluster structure

As can be seen in Figure 1, the number of segments in the cluster also affects the duration of /s/ ( $F=61.76$ ;  $p<.001$ ). As a single consonant, the /s/ is significantly longer ( $\mu=146$  ms) than as constituent of a two-segment cluster ( $\mu=120$  ms), which in turn is longer than as a member of a three-segment cluster ( $\mu=100$  ms). The mean durations in ms are shown in Table 2.

	+ focus			- focus		
	$\mu$	$\sigma$	n	$\mu$	$\sigma$	n
s	171	55	100	122	25	100
sC	142	43	400	98	25	400
sCC	117	45	150	84	26	150

Table 2. The durations in ms of /s/-frication as singleton, member of two-segment cluster and three-segment cluster in focal and non-focal accent conditions across different positions in the word.

The relatively high degree of standard deviation, especially in the focal accent condition, is probably due to individual differences between the nine subjects' productions.

These data confirm the general tendency for consonants to be shortened when they occur within a consonant cluster (e.g. Swedish: Lindblom et. al. 1976; English: Klatt, 1973, 1974). The reason for this shortening have been discussed in terms of physical constraints on the speed of various articulators, and a desire of the speaker to maintain overall syllable or word duration (e.g. Klatt, 1973).

#### Position in the word

The duration of /s/ is also affected by its position in the word ( $F=20.04$ ;  $p<.001$ ). In this material no word-final three-segment consonant clusters occur. The /s/ segments as word-initial singletons or as members of word-initial two-segment clusters are shorter than the corresponding word-final /s/ segments. Furthermore interactions were found between cluster structure and position in the word ( $F= 5.3$ ;  $p=.021$ ). While the /s/ segment as constituent in word-initial two-segment clusters is shorter ( $F= 55.35$ ;  $p<.001$ ), no reliable difference was found between word-initial and word-final single /s/ segment durations ( $F= .214$ ; n.s.). The main durations in ms are shown in Table 3.

	word-initial			word-final		
	$\mu$	$\sigma$	n	$\mu$	$\sigma$	n
s	143	42	100	150	55	100
sC	113	42	500	132	39	300
sCC	100	40	300	-	-	-

Table 3. The durations in ms of /s/-frication as singleton, member of two-segment cluster and three-segment cluster in different positions in the word, across focal and non-focal accent conditions.

In English, Klatt (1976) observed that consonants in word-initial position had the longest duration, followed by the duration of consonants in word-final and word-medial positions. He also discussed whether there are observable affects of word-final lengthening. In Swedish, the single /s/ segment seems to have the same duration in monosyllabic words in word-initial and

word-final positions. This similarity might be explained by resyllabification: the word-final /s/ belongs to the next syllable as its onset. The picture is different regarding the /s/-duration in two-segment clusters. The /s/-segment in two-segment clusters in word-final position is significantly longer than in word-initial clusters. The second member of a word-final cluster can be considered to take part in the process of resyllabification, while the /s/ remains part of the syllable as its coda and undergoes final lengthening.

#### Phonological length of the preceding vowel

A two-way analysis of variance (prominence x phonological length of preceding vowel) was calculated for the duration of /s/. This analysis included only the two words *fas* and *kass*. In these words the target /s/-segment occurs as singleton in word-final position. The aim of the analysis was to investigate the combined effects of the focal and non-focal accent and the phonological length of the preceding vowel on the duration of /s/. The phonological length of the preceding vowel affects the duration of the single /s/-segment ( $F=37.44$ ;  $p<.001$ ). The /s/-segment is shorter when it follows a phonologically long vowel ( $\mu=149$  ms) than a phonologically short vowel ( $\mu=192$  ms). In words with focal accent the /s/ duration following a phonologically short vowel is longer ( $\mu=228$ ) than in words without focal accent ( $\mu=155$  ms) ( $F=55.57$ ;  $p<.001$ ). Similarly, following a phonologically long vowel the /s/ duration in words with focal accent is longer ( $\mu=175$  ms) than in words without focal accent ( $\mu=124$  ms) ( $F=27.44$ ;  $p<.001$ ). No interactions between prominence level and phonological length of preceding vowel were found. However, the difference between the duration of /s/ in focal and non-focal stress condition seems to be larger ( $\Delta = 73$  ms) following short vowel than following long vowel ( $\Delta = 51$  ms). These results are presented in Figure 2.

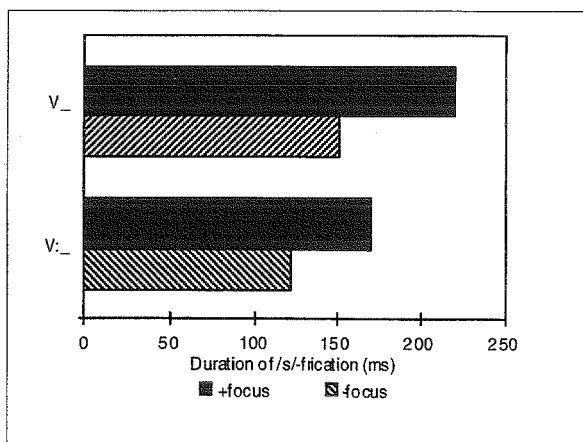


Figure 2. The duration of /s/ as single segment following phonologically short (n=45) and long (n=45) vowel in words with and without focal accent.

The same observation about the difference of the durational increase of the consonant following stressed long and short vowel respectively, in and out of focus, was reported by Bannert (1979) for Standard Swedish. He measured the durations of the unaspirated consonant /k/ following the stressed front rounded vowel /œ/ in bisyllabic words. It might be argued that due to the Swedish quantity system and the phonological pattern of complementary length, the temporal signalling of focus accent, besides the F<sub>0</sub>-rise, is mainly projected into the long segment of the /VC/-sequence. The temporal pattern of complementary length is also to be found in Central Bavarian. In an attempt to phonetically model the temporal shape of this pattern, Bannert (1976) tried to show that the complementary pattern of the VC-sequence appears to be very stable, in spite of relatively large variations of the duration of each of the members of the VC-sequence.

## CONCLUSIONS

The results of this investigation show some aspects of temporal variation of the consonant /s/ as singleton and as member of consonant clusters under different conditions. As an additional contribution to earlier findings concerning phonetic and phonological aspects of Standard Swedish consonants, the present research will widen our knowledge considerably. This is due to the large number of speakers, the scope of the test material including six selected consonants in a strictly controlled material and in free speech. The large amount of data to be published later will facilitate comparisons between languages. After having calculated the grand means for the nine speakers (the data of the tenth speaker is being added) and having described the variation patterns for the whole group, the analysis will continue studying in detail the individual patterns of temporal variation in consonants.

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## REFERENCES

- Bannert, R. (1976) *Mittelbairische Phonologie auf akustischer und perzeptorischer Grundlage*. Travaux de l'Institut de Linguistique de Lund X. (Gleerup: Lund).
- Bannert, R. (1979) "The effect of sentence accent on quantity", Proceedings of the IXth International Congress of Phonetic Sciences, Copenhagen, Vol II, 253-259.
- Bannert, R., Czizler, P.E., Karst, N. & Landgren, T. (1996) "Temporal variation in Swedish consonant clusters: preliminary data", *TMH-QPSR* 2/1996, 25-28.
- Bruce, G. (1977) *Swedish word accents in sentence perspectives*. Travaux de l'Institut de Linguistique de Lund XII. (Gleerup: Lund).
- Czizler, P.E. (1993) "Temporal variation in consonant clusters in Swedish", Proceedings of the 3rd European Conference on Speech Communication and Technology, EURO-SPEECH '93, Berlin, 469-471.
- Elert, C-C. (1964) *Phonologic Studies of Quantity in Swedish*. (Almqvist & Wiksell: Stockholm).
- Elert, C-C. (1970) *Ljud och ord i svenskan*. (Almqvist & Wiksell: Stockholm).
- Klatt, D.H. (1973) "Durational Characteristics of Pre-stressed Word-Initial Consonant Clusters in English", MIT Res. Lab. Electron., Q. Prog. Report No 108, 253-260.
- Klatt, D.H. (1974) "The duration of [s] in English words", *J. Speech and Hear. Res.* 17, 51-63.
- Klatt, D.H. (1976) "Linguistic uses of segmental duration in English: Acoustic and perceptual evidence", *J. Acoust. Soc. Am.* 59, 1208-1221.
- Lindblom, B. & Rapp, K. (1973) "Some temporal regularities of spoken Swedish", Publication No 21. Institute of Linguistics, Stockholm University.
- Lindblom, B. Lyberg, B. & Rapp, K. (1976) *Durational patterns of Swedish phonology: Do they reflect short-term motor memory processes?* Institute of Linguistics, Stockholm University.
- Melin, O.W., (1927-29) *Stenografiens historia I-II*. Stockholm.