**SWEDISH CONSONANT CLUSTERS IN SPONTANEOUS SPEECH: PRELIMINARY ACOUSTIC-PHONETIC OBSERVATIONS**

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**ABSTRACT**  
Compared to other parts of the Swedish phonological system, consonant clusters have not been studied sufficiently. This is especially true of the phonetic aspects. Therefore, the research programme “Variations within consonant clusters in spoken Swedish (VaKoS)” was launched, aiming at highlighting their occurrence and distribution in spontaneous speech, their temporal variations and the phonological processes operating on them. Preliminary data from the spontaneous speech of one female Standard Swedish speaker is presented.

**INTRODUCTION**  
From a typological and universal point of view, Swedish is characterized by a relatively complex syllabification structure. Within a morpheme, the syllable nucleus may be preceded and followed by three consonants, e.g. *strafl* (penalty), *väkt* (plant). Within the syllabic domain, five consonants may follow, e.g. *skälmskt skratr* (roguish laughter). Consonant clusters of eight consonants, at least in the canonical view, can arise across word boundaries, e.g. *skalmski skratt* (roguish laughter). However, in fluent speech, some consonant clusters are normally deleted. The prosodic feature of quantity intersects in an intriguing way with consonant clusters in morphemes and syllables. Shedding light on this important area of Swedish phonology that has not yet received due attention, is the goal of the project “Variations within consonant clusters in spoken Swedish (VaKoS)”.

The project aims at describing the occurrence, distribution and temporal variation of consonant clusters in phonetically controlled and spontaneous Standard Swedish speech. Phonological processes operating on these clusters will also be studied. Speech samples of one hour’s length of five male and five female Standard Swedish speakers of similar background will be collected in the database DUKoS (Databasen i Umeå för svenska konsonantgrupper). The investigation will also include perceptual experiments.

**BACKGROUND**  
Phonotactic aspects of consonant clusters are treated in [1]. The domain of analysis is the word and a generative programme for possible consonant clusters in Swedish is developed. Compared to the morpheme as the domain of analysis, this approach yields larger clusters.

In a classic work [2], an attempt to write rules for phonological processes operating on consonant clusters was made. In contrast to [1], spontaneous speech was the goal of that investigation. It also treated clusters that arise across word boundaries.

Variations within consonant clusters from a phonological point of view are treated in [3]. Typical processes are deletion, assimilations and retroflexion. However, experimental studies concerning spontaneous speech and quantitative aspects of consonant clusters including phonological processes have not been conducted.

Experimental data concerning the temporal pattern of variation of consonant clusters consisting of *ts, tk, kl* in initial, medial and final morpheme position in phonetically controlled utterances were presented by [4]. A linear increase of consonant and cluster durations of about 40 ms due to focus accent applies to all positions.

**GOAL**  
The goal of the present study is to collect preliminary acoustic-phonetic data on Swedish consonant clusters in spontaneous speech. Three main aspects are dealt with: first, the frequency of occurrence of consonant clusters with respect to word and morpheme boundaries. Second, the distribution of phonological processes affecting consonant clusters and their phonetic manifestations. Third, the segmental composition of the clusters.

**MATERIAL**  
Two adult speakers, two males and two females, aged between 30 and 40, from the Stockholm area were recorded. The spontaneous speech of each speaker, approximately 60 minutes each, was organized into four different topics with the duration of about 15 minutes each.

The topics included summer holiday, cooking, literature and body language. Recordings of the speech wave and the electro-laryngograph signal were made simultaneously. This signal makes it possible to clearly observe the actions of the glottis during consonant production. The preliminary data presented here comprises one topic about body language by the female speaker. A passage at the beginning of the text is shown:

"... då för mej blir de ålså valdit valdit jobbat att försöka dela hålla tråden så att vi få gjort de som vi ska få gjort eft de vill säga ja hinner spruta ut all min kunskap å dels att ja hinner avläsa inte bara på dom som sitter längst frans "

The text is represented in a simplified orthography expressing the way of pronunciation in this spontaneous speaking style. The following prosodic markers are inserted:

- **Phrase boundaries:**
  - I strong phrase boundary
  - I weak phrase boundary
  - CV primary stress (word accent)
  - CV secondary stress

**ANALYSES**  
In a preparatory phase, the material was labelled on a SUN Sparc2 station using ESPS/waves+. Four levels of labelling were selected: (1) an orthographic representation as close as possible to actual pronunciation, (2) non-verbal behaviour like laughter, clicks, in- and exhalations, (3) prosodic features of phrase boundaries and four levels of prominence (see above) and (4) consonant clusters. For the first level, we found methodological inspiration in the work of the Gothenburg linguists [5].

Figure 1 gives an illustration of a short passage contained in the text sample given in italics above.

When specifying the consonant clusters in the speech sample, we started out from the underlying or canonical word form. Retroflex consonants in morphemes are analysed as single segments (phonemes). Thus ‘bord’ (table) contains an initial and only one final consonant. Retroflex consonants, however, arise as the result of the phonological process of retroflexion across morpheme and word...
boundaries, e.g. 'smor+d' (greased), 'spar+sam' (economical), 'vårdag' (spring day).

Together with the segmental composition of the clusters, morpheme and word boundaries are indicated. We found it necessary to differentiate between a simple word boundary within a compound word (mat#sal, 'dining-room') and a double word boundary delimiting words (##fonster##, 'window'). Sometimes it was difficult to decide the morphological status of word elements. Numerals like 'sexti' (sixty), words like 'månda' (Monday) and 'dår' (dwarf) were treated as one morpheme. The reason for this decision is phonological and morphological: these words have the acute accent and for the language user of today these words cannot be divided into meaningful parts.

RESULTS
The preliminary results of this introductory study are presented in three groups: (1) occurrence of the consonant clusters expressed as their frequency, (2) the phonological processes, (3) their segmental composition.

Occurrence and frequencies
The speech sample studied had the length of about 12 minutes. It contained 1,000 consonant clusters. The ten most frequent consonant clusters are given under three conditions: (1) total in Table 1, (2) in morphemes (initially, medially, finally) in Table 2, (3) across word boundaries in Table 3. The first column in each table gives the frequency of occurrence, the second the consonant cluster in IPA notation and the third an example context. Segments in parentheses are deleted in the speech signal.

Table 1. Overall occurrences of consonant cluster. Total: 1,100.

Table 2. Consonant clusters in morphemes. Initial: total 57

Table 3. Consonant clusters across word boundaries. Total: 620

The frequency distribution of the consonant clusters in the three contextual categories above is rather similar. While 252 clusters appear only once in the speech sample, 64 clusters only twice, 35 clusters only three times, etc., one cluster is to be found 37 times and the most frequent one 39 times (cf. Table 1).

Phonological processes
By far the most frequent phonological process observed is consonant deletion, in total 360 instances. Final /t, r/ are deleted most frequently. Table 4 gives all the deletions found in the speech sample.

Table 4. Consonant deletions and their frequency. n = 360.

Segmental composition
Consonant clusters within morphemes will be used in order to illustrate their segmental composition. Table 5 gives an overview showing 2- and 3-consonant clusters, grouped according to the features obstruct, nasal and liquid.

Table 5. Segmented composition of 290 morpheme internal consonant clusters. Two and three segments.

CONCLUSIONS
We have developed a method and procedure that ensure a quantitative and qualitative processing of spoken Standard Swedish with respect to the analysis and phonetic description of consonant clusters. The largest difficulty encountered is morphological segmentation. We decided to give priority to the diachronic aspect and to disregard the synchronic aspect and to disregard the diachronic processing. The preliminary results of our project work are promising.

The data on the occurrence and frequency distribution of the consonant clusters, the distribution of the various phonological processes and the specification of their segmental composition will contribute substantially to our knowledge of the phonotactic structure of Standard Swedish. Our results will also deepen our insights into the typological dimension of consonant clusters. Furthermore, this is of great interest to experimental phonology. One side-effect of our work, due to excellent computer facilities, will be a corpus of spontaneous speech labelled for prominence, morpheme, phrase and word boundaries, consonant clusters and even non-verbal signals. At the end, it will be available on CD-ROM. We plan also to publish the first frequency word list of spontaneous Swedish, sorted forward and backward, based on five hours of recording of five male and five female adult speakers.

REFERENCES