The Production of Swedish Sibilants - an EPG Analysis

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ABSTRACT

The sibilantic groove was EPG analysed in Swedish /s/, /ç/ and [ʂ], pronounced by ten speakers, in isolation and in phrases with varying vowel context. Interindividual variation was great and intraindividual variation small for groove position and width of each sibilant. In phrases, [ʂ] had the same groove front opening position as /ç/, but in isolation it was further back. /ç/ was constantly alveolar, except being palatal for one speaker in /i:/ context. The groove length was greater in /s/ and /ç/, and smaller in [ʂ]. There was no or very little correlation between groove width and sibilantic identity.

INTRODUCTION

Acoustic modelling of fricative production has advanced in the last decade (Shadle 1990, Badin, 1991, Scully et al, 1992). For further development, the need for empirical production data is great (e g Baer et al, 1991). One important practical application of this growing knowledge is to give a scientific phonetic base to dental prosthesis constructing (Lundqvist, 1993). Especially [s] is often deteriorated by prostheses (Lundqvist, 1993).

With three phonemically contrasted front tongue sibilants - /s/, /ç/ and [ʂ] - Swedish is especially suitable for an investigation with the aim to further the development of the fricative modelling work. These sounds are acoustically and perceptually closely related. /ç/ is intermediate perceptually in brightness, and acoustically in spectral energy distribution (Lindblad, 1980). (For articulatory descriptions of these sounds, based on profile cineradiography, see Lindblad (1980); [ç] is also described in Lindblad (1978)) [ʂ] is a common allophone of the Swedish /ʃ/ phoneme, which also has a common, non-sibilantic allophone, [ɧ].

The best way available to analyse the sibilantic groove - one of the two crucial articulatory features in sibilants - is by electropalatography (EPG) (Hoole et al, 1989). This method has been used in several studies of sibilantic production e g in English (e g Hoole et al, 1989, Fletcher & Newman,1991). Swedish sibilants have been treated in two EPG investigations: of /s/ (Lundqvist et al, 1993), and of a large number of consonants, including /s/, /ç/ and [ʂ] (Engstrand, 1989). Several EPG studies are based on very few speakers.

The other crucial articulatory feature in sibilants is the incisors, being hit by an air jet emanating from the groove. About this phenomenon, neither EPG nor any other existing method gives direct information. However, the combination of EPG data with jaw movement and acoustic information, and dental casts of the upper and lower jaws, will be able to contribute to the advancement of the understanding of the role of this feature. We have procured this combination of data and have short-time plans to work with it, with due attention to important new theoretical aspects in Shadle (1990) of alveolar ridge and tooth contribution to the sibilantic source generation.

METHOD AND MATERIAL

Our equipment was of the Reading EPG type. For a thorough description, see Hardcastle et al (1989). In short terms, the speaker wears a thin palate, extending from the upper teeth back to the velum. In this palate, 62 electrodes are placed in a regular pattern. In the alveolar region, where the sibilantic groove is produced, both longitudinal and transverse inter-electrode distances are about 4 mm. The electrode diameter is 1.4 mm. The tongue contact pattern is registered 100 times/sec and stored in a computer.

Each EPG registration frame is a kind of map, representing the tongue-palate contact every 10 milliseconds. In this map, each electrode is represented by a specific point as either touched or free (untouched). The map points are arranged in a pattern, similar to the electrode pattern, with eight transverse rows and eight longitudinal columns of points. In our sibilantic groove analysis, we decided in which row the frontmost minimum constriction was (constriction place, CP), and counted the number of free electrodes in that row (constriction width, CW). Also back and front groove opening shapes were measured. All groove measure parameters were taken from Hoole et al (1989) and Engstrand (1989).

In parallel with EPG registration, also optoelectronic recording of jaw movements and acoustic registration were made, at the Dept of Prosthetic Dentistry, University of Göteborg. (We thank Agneta Erneman for her skilful assistance.)

Our investigation was based on 10 Swedish speakers, 4 women and 6 men (mean age 31 years, range 23-49 years). All had normal speech without strong dialect or hearing deficits. Six spoke variants of central Swedish, 4 spoke south Swedish variants. South Swedish lacks [ʂ], but each of /s/ and /ç/ are produced in the same way in all Sweden, just as [ʂ] in central Swedish (Lindblad, 1980).

The subjects had worn dummy palates, similar to the EPG ones, during a whole fortnight two years before, in connection with another study. In this study, they wore these dummy palates for four hours or more before each of three registration sessions.

The material consisted mainly of various long, natural phrases with the three sibilants in systematically varied vowel context - [i a u], produced long or short. (For /s/, the consonant context, stress and phrase position were varied, too, but the effect of these parameter changes are not reported here.) Also isolated pronunciations of the sibilants were registered. The whole material was produced nine times.

RESULTS AND DISCUSSION

Inter- and intraindividual variation

Interindividual variation was great and intraindividual variation small for groove position and width of each sibilant. This agrees with other sibilant studies (e g Bladon & Nolan, 1977, Lindblad, 1980, Fletcher & Newman,1991, Lundqvist et al, 1993). The main explanation of the interspeaker variability is that speakers with different shapes and sizes of teeth, alveolar ridge, jaw, and front tongue must reasonably produce the sibilantic groove in different ways as concerns the details, in order to achieve similar acoustic and perceptual results (Lindblad 1980, Lundqvist et al 1993). The small intraspeaker variability is probably mainly explained by the strong demands on preciseness in directing the air jet against the front teeth in sibilants (Lindblad, 1980, Lundqvist et al 1993).

The /ç/-[ʂ] distinction

Not unexpected, /s/ was produced furthest in front, generally with a clear distance to /ç/ and [ʂ]. In phrases, these latter sounds had the same groove front end position, always mid alveolar - about 8-13 mm from the upper front incisors - except in one marginal case. Uttered in isolation, [ʂ] was however distinctly further backwords in 4 speakers and close to /ç/ in 3 out of 7. Also, the minimum groove width of these sounds was similar (usually below 7 mm). Often, their groove length, and back and front groove orifice width change shapes were also similar.

These facts support the hypothesis (Lindblad, 1980), that the articulatory place of /ç/ and [ʂ] is not their primary distinguishing articulatory feature. Instead, as expanded on in Lindblad (1980, p 79-81, 195), the articulatory discription of sibilants must attend more to the size of the groove anterior cavity. Perhaps also the groove posterior cavity shall be considered (Hoole et al, 1989), but according to Stevens (1991), only the anterior cavity is important for the resonance shaping.

The fact that two different phonemes have their constriction in the same position in a single speaker, and also often at the same time have similar groove width and length, has implications for the general system of consonant description, as expressed in the universally used IPA two-dimensional scheme of articulatory places and manners. This scheme is obviously the best general frame for consonantal classification, but it it not equally suitable for an adequate treating of distinctions within all classes of sounds. The sibilants are an evident example of this.

Secondary and primary palatal /ç/ constriction

Behind the alveolar groove in /ç/, and separated from it by a usually considerable widening of the vocal tract, an almost equally narrow secondary palatal constriction was found in 2 speakers, 15 to 20 mm back. In one of them this constriction was general in phrases, in the other it occurred before /i u/ but not /a/. Two other speakers had a related but much wider secondary palatal constriction. Still another speaker pronounced /ç/ before /i/ but not /a, u/, with a primary palatal constriction, which was quite narrow - on average between about 4 and 10 mm. In this exceptional case, /ç/ was palatal. Otherwise, /ç/ was alveolar, with a groove equal in width to /s/ and [ʂ], and equal in length to in /s/, but tending to be longer than in [s].

EPG data for one single central Swedish speaker in Engstrand (1989) disagrees with this general alveolar /ç/ pronunciation of 6 central and 4 south Swedish speakers. In the Engstrand study, the /ç/ constriction was consistently palatal and wide, with a position much further back than [ʂ]. This is similar to the exceptional /i/ context case above, except for the wide constriction. It is evident that the most common Swedish /ç/ pronunciation is alveolar.

Groove length

In most cases, the groove length of all sibilants was less than about 7 mm. A longer groove (up to about 11 mm) was found in all /s/ productions of 2 speakers, and in all /ç/ productions of 2 others, and also in some speakers' production of these sounds before high vowels. However, it was not found in [ʂ]. This tendency for a shorter groove in [ʂ] and in /a/ context appears to be caused by the lower tongue position in these sounds. Due to it, the front tongue has to be raised more, and a smaller part of it will make contact with the alveolar crest.

Groove width

On average, the groove width in /s/ was a little narrower than in the other two sibilants, which were quite similar. However, the differences were small and did not seem to be significant. (The statistical treatment of these data is not finished.) Each sound occurred with the closest groove in at least one subject, both in phrases and as isolated. In phrases, /s/ was closest in 4 subjects, and /ç/ and [ʂ] in one case each. However, in 4 subjects, the sibilants had fairly equal average groove widths. In isolation, the corresponding pattern was related, but the combination of individual speakers and closest sibilant was only partly identical. For example, as pronounced isolated, /ç/ had the narrowest grove in 3 subjects.

In phrases, the average width of each sibilant was near 2 CW units (i e 2 free electrodes, which corresponds to 5-11 mm) in 6 subjects. Two subjects had a generally closer constriction, around 1.5 units. Two subjects had a generally wider constriction around 3 units in /ç/ and [ʂ] - excluding /s/, with around 2 units. Obviously, each subject tended to have a general width style for all sibilants in phrases. This tendency was found also in isolated sibilants, but less pervading: Three subjects lacked this pattern there. The average groove width in isolated sibilants was however similar to the phrasal data.

This fairly constant groove width pattern in Swedish sibilants differs from English sibilants, where [ʃ] is significantly wider than [s] (Fletcher & Newman, 1991). This difference has to be analysed more closely.

Groove width variation, related to vowel context, was found in Swedish. The pattern was complicated. In [ʂ], the variation was great, but with no general pattern. For each of /s/ and /ç/, the variation was small in five subjects and considerable in five (whereof three subjects are the same). For /s/, there was a general pattern: The width was smallest before /a/ and greatest before /i/. The /ç/ variation pattern was partly similar, with greatest narrowness in /a/, but not greatest width in /i/.

Apparantly, this contextual /s/ and /ç/ groove width variation in several speakers had connection with tongue body position, especially height: Low tongue position was connected with a narrower groove. The same pattern was found in Lundqvist et al (1993), where the first /s/ in *A sadist* - [osa'dIst] - was significantly narrower and had a lower tongue body position context than the second /s/. It appears that when the tongue mass is lower, the conditions for the narrow shaping of the groove are more favourable.

One possible explanation of this pattern has to do with conditions for muscular cooperation: When the authors' tongue bodies are high and front like in /i/, the tongue blade feels stiff. In /a/ on the other hand, it is slack. To shape the sibilantic front tongue groove is probably the most complicated of all articulatory gestures: All seven tongue muscle groups cooperate with a delicate balance (Hardcastle, 1976). To create a narrow groove with a stiff front tongue should be especially difficult.

A more penetrating explanatory analysis of this kind of phenomenon will hopefully soon be possible, within the framework of the now developing, detailed tongue models (e g Stone, 1991). Empirical data patterns like the groove variation above may also serve as touchstones for parts of such models.

Another factor which might contribute to the observed pattern has to do with variation in mechanical resistance: When the tongue mass is close to the oral ceiling and pressed against it, the effort to lower its median longitudinal front part will meet more resistance than otherwise. Therefore, the muscular effort to create the groove will be distributed horisontally to a greater extent.

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