GROOVE WIDTH IN CROATIAN VOICED AND VOICELESS POSTALVEOLAR FRICATIVES

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ABSTRACT

The aim of this investigation is to use a newly available electropalatography (EPG) index to quantify groove width characteristics in Croatian postalveolar fricatives. Six normal adult speakers of Croatian produced 648 nonsense VCV sequences (V: /i/, /a/, /u/; C: /ʃ/, /ʒ/). Anterior groove width (AGW), posterior groove width (PGW), intraspeaker and interspeaker variability were quantified. Results show that groove width is gradually narrowing towards the front of the oral cavity. AGW is virtually unaffected by vowel context, while PGW shows less coarticulatory resistance. AGW and PGW characteristics show opposite tendencies in voiced and voiceless fricatives in that AGW is slightly wider in voiceless than in voiced fricative, while voiced fricative is produced with a wider PGW than the voiceless one. The results also show that groove width variability is very low. The importance of groove width characteristics quantification for clinical use is discussed.

Keywords: electropalatography, postalveolar fricatives, groove width, voicing, Croatian

1. INTRODUCTION

Until one recent unpublished investigation [10] the physiology of Croatian fricative productions has not been previously instrumentally studied. Several articulatory characteristics are considered essential for the production of anterior lingual fricatives; a narrow midline groove is among the most commonly mentioned characteristics. In order to maintain the characteristic fricative groove, a precise relationship between the active (tongue tip/lamina) and the passive articulator (incisors/alveolar ridge/prepalatal zone) needs to be established. This relationship can be closely studied by means of electropalatography (EPG). EPG is the only physiological instrumental tool which provides a direct and detailed insight into tongue-to-palate contact patterns during speech. The formation of the narrow midline groove is necessary for most lingual fricatives [8, 9]. Studies have shown that tongue-to-palate characteristics of that groove are important to distinguish between different fricative types [3, 4, 14]. A variation of only one millimetre in the crucial part of the vocal tract during fricative production can make a great difference [8]. Therefore, precise quantification of tongue-to-palate groove width is an important aspect of fricative production description. The lack of normative physiological data on such an important aspect of Croatian postalveolar fricative production, prompted us to provide the analysis of tongue-to-palate characteristics of groove width in Croatian /ʃ/ and /ʒ/. Clinical practice will also benefit from this investigation, because these hard-to-treat consonants proved to be among the most commonly targeted sounds in therapy [7, 11].

Apart from specifying typical electropalatographic characteristics, it is also important to determine typical variability of groove characteristics. Quantification of variability is especially important for clinical practice, because a wide range of variations produced by normal speakers can often make it difficult to identify atypical productions in disordered speech [6, 12].

Fricatives /ʃ/ and /ʒ/ differ according to voicing. Supraglottal cues for voicing in fricatives seem somewhat unclear, especially when electropalatographic data are taken into account [2, 5, 13].

Considering the above, the aim of this study is to utilise a measure that is newly available in the EPG software [16] in order to: first, quantify groove width characteristics in Croatian postalveolar fricatives, second, investigate how groove width characteristics are influenced by the difference in voicing status, and third, quantify the variability of groove width measure in these consonants.

2. METHOD

2.1. Speakers

There were three female (F1, F2, F3) and three male (M1, M2, M3) participants in this study. All six speakers were normal adult speakers of Croatian, aged between 26 to 35 years, with the mean of 30.8 years. Each speaker had an artificial palate individually constructed to fit against the hard palate (The Articulate palate, [15]).

2.2. Speech material

Speech material was extracted from the Croatian acoustic and electropalatographic corpus (HEK). Analysed material consisted of nonsense VCV sequences in which V represented three corner vowel positions: /i/, /u/ and /a/, while C represented consonants /ʃ/ and /ʒ/. Each speaker repeated the sequence of 18 words six times, resulting in the total of 648 items with short-falling accent placed on the first syllable.

2.3. Procedures

Speech data were recorded by WinEPG system. EPG data were sampled at 100 Hz. Acoustic data were recorded simultaneously using M-Audio MobilePre external USB sound card/pre-amplifier with the sampling rate of 22050 Hz. Annotation, segmentation and data preparation was performed by the Articulate Assistant software [16]. MS Excel was used for statistical analysis and data visualization. All participants underwent a desensitization period in two phases. The first phase consisted of five days with two-hour palate-wearing sessions each day. The second phase of desensitization procedure was prior to the recording and lasted for the maximum of one hour. The recording procedure began only when speaker's articulation was rated as acceptable by two trained phoneticians.

2.4. Data analysis

EPG characteristics of fricative groove width were analysed using the mean lateral measure available in the Articulate Assistant software [16] at the point of maximum contact. It measures whether there is more contact at the midline of the palate or more contact towards the lateral sides. Higher value indicates greater groove width. Groove width was measured separately for the anterior (AGW: the front four rows of electrodes) and the posterior part of the palate (PGW: the back four rows of electrodes).

Statistical variability was quantified by dividing the standard deviation by the mean and it was expressed as a percentage. Variability within a particular speaker (intraspeaker variability) and between speakers (interspeaker variability) was analysed.

Differences in the groove width between voiced and voiceless postalveolar fricative were also quantified.

All differences were tested for statistical significance using heteroscedastic t-test.

3. RESULTS

3.1. Groove width

Results presented in figures 1 and 2 show that Croatian postalveolar fricatives have somewhat narrower AGW (/ʃ/ 0.7, SD 0.04; /ʒ/ 0.69, SD 0.04) than PGW (/ʃ/ 0.75, SD 0.04; /ʒ/ 0.77, SD 0.04).

Figure 1: AGW and PGW in voiceless fricative /ʃ/ in each speaker.

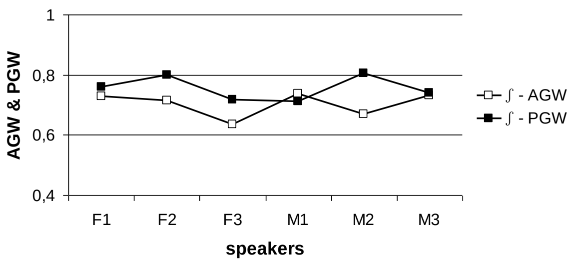
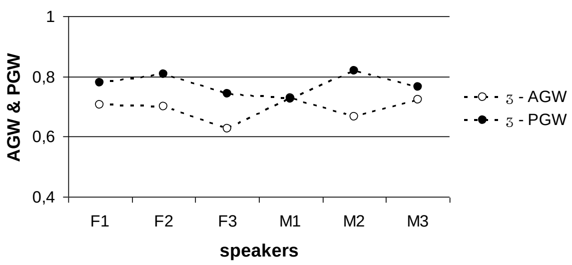
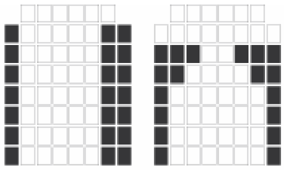


Figure 2: AGW and PGW in voiced fricative /ʒ/ in each speaker.



Although the average difference is small, it can be observed in almost every speaker, the only exception being M1 (figure 3). The difference between AGW and PGW is statistically significant ($p<0.01$) in four speakers (F1, F2, F3, M2) and in the fifth speaker (M3) it is significant in the voiced fricative only ($p<0.01$).

Figure 3: Electropalatograms at maximum contact point in /aʃa/. M1 (left) with similar AGW and PGW compared to M2 (right) with significantly different AGW and PGW.



Groove width is generally highly resistant to the influence of surrounding vowels. There is no statistical difference between different vowel contexts in the AGW in either of the fricatives ($p>0.05$). In the PGW some of the vowel contexts produce significantly different ($p<0.05$) groove widths in /ʃ/ (/aʃa/ and /aʃu/ significantly differ from /iʃa/, /iʃi/, /iʃu/, /uʃa/, /uʃi/, /uʃu/) as well as in /ʒ/ (/aʒa/ and /aʒu/ differ significantly from /iʒi/, /uʒa/, /uʒi/, /uʒu/). However, most vowel contexts do not produce significantly different PGW in these fricatives ($p>0.05$).

3.2. Groove characteristics and voicing

AGW and PGW results show opposite tendencies in voiced and voiceless fricatives (figures 4 and 5). All speakers produce the voiceless fricative with a slightly wider AGW than its voiced counterpart. On the other hand, voiced fricative is produced with a wider PGW than the voiceless one. The difference between voiced and voiceless fricative in the AGW is statistically significant ($p<0.01$) only in F1. The difference between /ʃ/ and /ʒ/ in the PGW reaches statistical significance ($p<0.05$) in three speakers (F1, F3, M3). The overall groove width difference between voiced and voiceless fricative is greater in the posterior palate (PGW difference: 0.02) than in the anterior palate (AGW difference: 0.01).

Figure 4: AGW in postalveolar fricatives in each speaker.

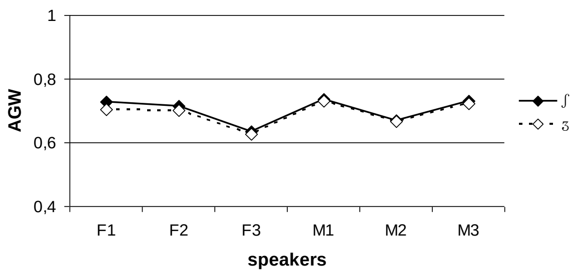
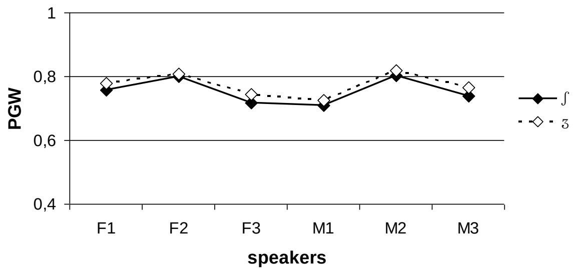


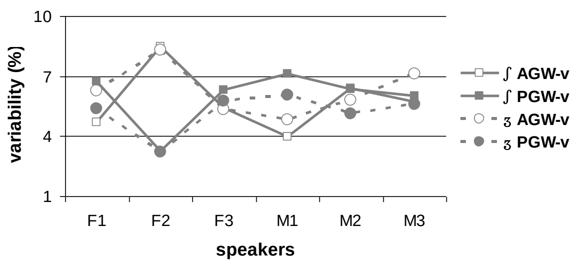
Figure 5: PGW in postalveolar fricatives in each speaker.



3.3. Groove width variability

Average intraspeaker groove width variability (figure 6) is very low and it is similar in voiced and in voiceless postalveolar fricative both in the anterior (/ʃ/ 5.78%, SD 1.56; /ʒ/ 6.26%, SD 1.27) and in the posterior part of the palate (/ʃ/ 5.96%, SD 1.38; /ʒ/ 5.18%, SD 1.01). In the anterior half of the palate three speakers produce /ʃ/ with more variability (F2, F3, M2), while the other three speakers (F1, M1, M3) have more variability in /ʒ/. In the posterior part of the palate all speakers produce /ʃ/ with more variability.

Figure 6: AGW and PGW variability in postalveolar fricatives in each speaker.



The difference between AGW and PGW variability is not the same in all speakers. All speakers have higher PGW variability, except F2, whose AGW variability is very high. Thus, AGW variability ranges from 3.99% in /ʃ/ and 4.8% in /ʒ/ (M1) to 8.49% in /ʃ/ and 8.29 in /ʒ/ (F2). On the other hand, PGW variability ranges from 3.25% in /ʃ/ and 3.21% in /ʒ/ (F2) to 7.12% in /ʃ/ and 6.05% in /ʒ/ (M1). Interspeaker variability is slightly higher in the anterior part of the palate and it is higher in /ʃ/ (AGW variability: 5.87%, PGW variability: 5.29%) then in /ʒ/ (AGW variability: 5.62%, PGW variability: 4.69%).

4. DISCUSSION

As expected, AGW is slightly narrower than PGW, indicating a long, gradually narrowing groove in both fricatives. Other studies have also quantified groove width in fricatives, e.g. [3, 4], but the novelty of this study is the quantification of the AGW and PGW separately, showing gradual narrowing of the groove. This relationship between the AGW and the PGW can be used to distinguish between different types of anterior lingual fricatives. In a recent unpublished EPG investigation of Croatian sounds [10] it is reported that alveolar fricatives have narrower AGW and wider PGW, which indicates shorter groove length than that in postalveolar fricatives analysed here. Fletcher and Newman [4] also report on a longer groove width in postalveolar than in alveolar fricatives. Further investigation is required to find out how speakers like M1 achieve normal frication in the absence of a classic "funnel" shape for these fricatives. Results of the present study also show that groove width is remarkably resistant to coarticulatory effects of neighbouring vowels. This is consistent with other EPG investigations of fricatives [2, 13]. AGW and PGW analysis in this study shows that AGW is virtually unaffected by vowel context, but that PGW shows less coarticulatory resistance.

Data in this paper show that voiced and voiceless fricatives have different characteristics of AGW as opposed to PGW. These differences are very small and sometimes the difference is in one electrode only. However, it is worth keeping in mind that an average contact separation in the first four rows of the Articulate palate is about 3mm [15]. Three millimetre difference is a rather large difference for an average groove width of about 11mm found in postalveolar fricatives [3, 4]. Slightly wider PGW in voiced fricative supports claims that fricatives might manipulate constriction size behind the place of articulation in order to facilitate voicing [4], especially since voiced fricatives in Croatian need to maintain full voicing throughout their duration [1].

Groove characteristics of postalveolar fricatives are important not only for phonetic theory, but also for clinical practice. Fricative /ʃ/ is among most commonly targeted sounds in EPG therapy [7] and extremely difficult to treat using traditional therapy [11]. Hasegawa, et al. (cited in [4]) found that trained aesophageal speakers manipulate groove width and placement to produce high-frequency noise in fricatives. Quantification of groove width using the mean lateral measure could prove useful for investigating fricative production differences and coarticulation processes in different fricative sounds. This measure might also provide new insights into fricative production mechanisms in disordered speech.

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