ELECTROPALATOGRAPHIC ANALYSIS OF /ɲ/ AND /ʎ/ IN CROATIAN

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ABSTRACT

Croatian sounds /ɲ/ and /ʎ/ are traditionally classified as palatal, but the lack of instrumental articulatory data causes uncertainties about their true articulatory characteristics. Since it was recently proposed that two groups of sounds could be identified within the group traditionally labelled as "palatal" in the International Phonetic Alphabet (i.e. alveolopalatal and palatal), it was our aim to investigate articulatory characteristics of /ɲ/ and /ʎ/ and see whether these two sounds have the characteristics of alveolopalatal, palatal or palatalized sounds. For this purpose we used electropalatographic data from six native speakers of Croatian. The results showed that there was no evidence of a purely palatal production of these sounds and that they were predominantly produced as alveolopalatals. The analysis also showed that /ʎ/ was more fronted and more variable than /ɲ/. There were significant inter-speaker differences in all variables.

Keywords: articulatory phonetics, electropalatography, alveolopalatals, Croatian.

1. INTRODUCTION

It was recently shown that not all consonants labelled as "palatal" in the International Phonetic Alphabet [5] shared similar articulatory gestures and that at least two articulatory categories could be identified within the group of consonants traditionally described as palatal: alveolopalatal and palatal [11]. Alveolopalatal place of articulation involves a constriction in the (pre)palatal and alveolar zones using the tongue blade and dorsum [11]. Palatal place of articulation, on the other hand, involves a constriction across the palatal zone using the tongue dorsum [11]. Both of these sound categories are produced at a single place of articulation and do not exhibit characteristics of complex sounds [10, 11, 12]. Secondary articulation such as secondary palatalization involves the formation of the primary place of articulation and the separate and gradually increasing formation of the secondary articulation at the palatal zone using the tongue dorsum [7, 9, 13]. During secondary palatalization the tongue dorsum activity is relatively independent of the tongue front activity and maximum constriction at the tongue dorsum is expected much later than at the tongue front [13].

Recasens [11] presented data from 29 world's languages and showed that consonants /çcjʎɲ/ can most frequently be classified as alveolopalatal and that /çcjɲ/, but not /ʎ/, may exhibit purely palatal articulation. Recasens's studies [11, 12] also showed that there were speaker-specific and language-specific differences affecting articulatory and coarticulatory characteristics of (alveolo)palatal productions, which led to the conclusion that data from other languages should be used to cast more light on these speaker- and language-specific issues.

One of the languages in which instrumental physiological data for (alveolo)palatal sounds is currently relatively lacking is Croatian, while instrumental speech production data for /ɲ/ and /ʎ/ are non-existent. Croatian sounds /ɲ/ and /ʎ/ are most frequently classified as palatal [5, 2, 6, 14]. However, attempts at more detailed descriptions of these two sounds reveal possible uncertainties about their true articulatory characteristics. While some authors describe /ɲ/ and /ʎ/ as postpalatal [2], others describe them as prepalatal [6] and mid-palatal to prepalatal [14]. Škarić [14] also notes that they are palatalized, although there is no explanation how a sound can be palatal and palatalized at the same time. It is therefore not clear whether these Croatian sounds are true palatals, alveolopalatals or palatalized (dento)alveolars.

In this study we are focusing on investigating articulatory characteristics of /ɲ/ and /ʎ/ in Croatian using electropalatography [3]. Our aim is to address three research questions: 1. do /ɲ/ and /ʎ/ share similar articulatory characteristics or not, 2. do articulatory characteristics observed in these sounds show that they are palatal, alveolopalatal or palatalized (dento)alveolars, and 3. do /ɲ/ and /ʎ/ differ in their variability (coarticulatory resistance) or not.

2. METHOD

2.1. Participants

Six native speakers of Croatian, aged between 26 to 35 years, with a mean of 30.8 years participated in this study. There were three female (F1, F2, F3) and three male (M1, M2, M3) participants with no history of speech, language or hearing impairments. Each speaker had an artificial palate individually constructed to fit against their hard palates (The Articulate palate) [15].

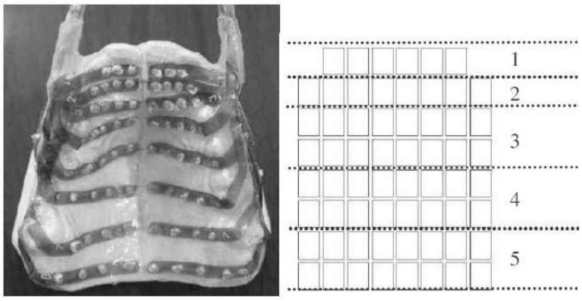
2.2. Speech material

Speech material was extracted from the acoustic and EPG corpus of the Croatian speech (CROELCO). 18 nonsense VCV sequences were used in this investigation, in which V represented three corners vowels in Standard Croatian (/i/, /a/, /u/), while C represented the two sonants (/ɲ/, /ʎ/). Those 18 sequences were repeated six times by each speaker, which resulted in 648 items, produced with a short-falling accent on the first syllable.

2.3. Instrumentation and recording procedure

The EPG data were recorded using the Articulate palate (Figure 1) connected to the WinEPG system, with the sampling rate set at 100 Hz. The acoustic data were recorded simultaneously using M-Audio MobilePre external USB sound card/pre-amplifier with the sampling rate of 22050 Hz.

Figure 1: Zoning scheme for the Articulate palate. (1 – dental, 2 – alveolar, 3 – postalveolar, 4 – palatal and 5 velar) (adapted from Wrench, 2007).



2.4. Data analysis procedure

Annotation and data preparation were performed by the Articulate Assistant software [16]. MS Excel was used for statistical analysis and data visualization. Sonants /ɲ/ and /ʎ/ were annotated according to EPG criteria: the annotation spanned between the first and the last EPG frames which showed complete electrode activation across one or more rows. Whenever there was no electrode activation across one or more rows, the sounds were annotated according to well established acoustic criteria as described in [8, 1].

Five EPG variables were analysed: relative contact placement using the centre of gravity measure (CoG), amounts of contact in alveolar, postalveolar and palatal articulatory zones, and EPG variability. The CoG measure [4] was used to quantify the relative location of the largest concentration of contacted electrodes on the EPG palate during the annotation. This measure was used to show the relative difference in contact placement between different speakers and different sounds. It was averaged for each speaker across all sequences. The amount of contact in the three articulatory zones (alveolar, postalveolar and palatal) was measured in order determine the details of tongue-to-palate contact activity during the annotation. These three measures were used to show whether articulatory gestures during /ɲ/ and /ʎ/ had the characteristics of palatal, alveolopalatal or palatalized (dento)alveolar sounds. These three measures were analysed for the whole annotation duration at a predetermined number of equally spaced sample points in order to show the temporal aspects of articulatory properties. The number of the sample points (nsp) for annotation was determined by the formula

(1) $$nsp = \frac{t}{10}$$

, where t was the duration of the shortest annotation in milliseconds (48 ms in this investigation) and 10 represented the distance between each EPG sample determined by the sampling frequency (100 Hz). EPG variability was used to quantify variability across all electrodes in an annotation caused by different vowel contexts. This measure was used to show which of the two analysed sounds showed more coarticulatory resistance. It was calculated for each speaker across all sequences.

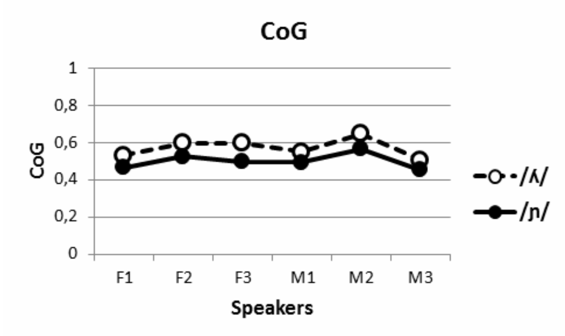
The significance of differences was tested using a two-way ANOVA with replication (alpha 0.05).

3. RESULTS

3.1. Relative contact placement

Figure 2 shows that /ʎ/ is consistently more fronted than /ɲ/ in all speakers. The relative contact placement of /ʎ/ ranges between 0.51 and 0.65 (mean 0.57, SD 0.05), while the placement for /ɲ/ ranges between 0.46 and 0.57 (mean 0.5, SD 0.04). Although the placement means are similar, the difference is statistically significant (F(1, 5)=1531.05, p<0.001). However, the statistical analysis also shows that the interaction between different speakers and sound type is also statistically significant (F(1, 5)=15.77, p<0.001).

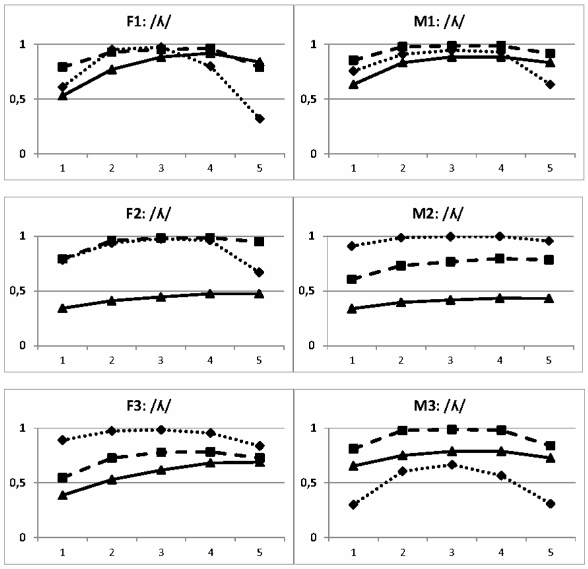
Figure 2: The CoG measure in /ʎ/ and /ɲ/ calculated for each speaker.



3.2. Alveolar, postalveolar and palatal contact

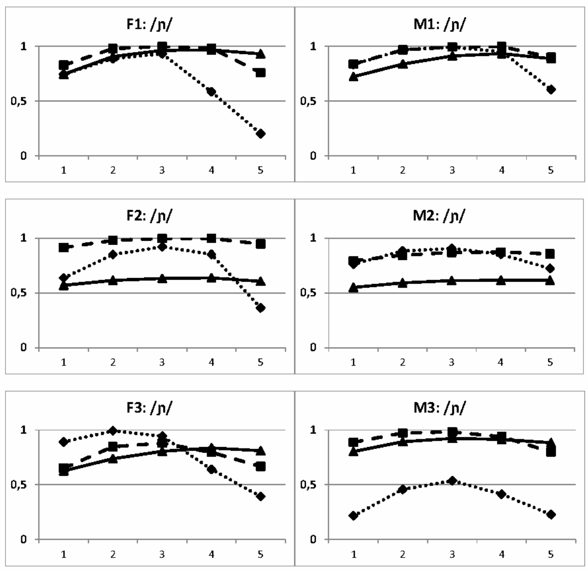
Visual inspection of the EPG contact analysis in alveolar, postalveolar and palatal zones in /ʎ/ shows that none of the six speakers produce this sound with the maximum contact exclusively in the palatal zone (Figure 3). All speakers produce this sound with maximum contact covering at least two traditional places of articulation. Speakers F1 and M1 produce /ʎ/ with the tongue-to-palate contact in the alveolar zone decreasing at the end of the annotation, while the EPG contact in the postalveolar and palatal zones remains relatively high. F2's production is somewhat similar to productions by F1 and M1, but the late decrease in the alveolar contact is not as large and palatal contact is much lower. The other three speakers (M2, F3, M3) produce /ʎ/ with similar tongue-to-palate contact dynamics in the three articulatory zones. M3 is the only speaker who produces /ʎ/ with the lowest contact in the alveolar zone.

Figure 3: Tongue-to-palate contact in alveolar (dotted line with diamonds) postalveolar (dashed line with squares) and palatal (solid line with triangles) zones at five equally spaced sample points measured during /ʎ/ in each speaker.



Similarly to the results for /ʎ/, the EPG contact analysis in alveolar, postalveolar and palatal zones during /ɲ/ shows that none of the six speakers produce this sound with the maximum contact in the palatal zone only (Figure 4). Visual inspection of the results shows that speakers F1, M1, F2 and F3 produce /ɲ/ with the tongue-to-palate contact in the alveolar zone decreasing at the end of the segment, while the EPG contact in the postalveolar and palatal zones remains relatively high. The other two speakers (M2 and M3) produce /ɲ/ with relatively similar EPG contact trendlines in the three articulatory zones.

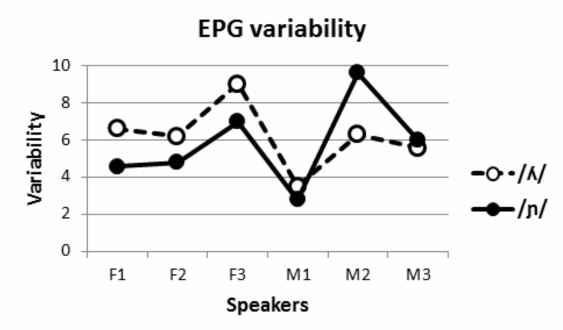
Figure 4: Tongue-to-palate contact in alveolar (dotted line with diamonds) postalveolar (dashed line with squares) and palatal (solid line with triangles) zones at five equally spaced sample points measured during /ɲ/ in each speaker.



3.3. EPG variability

The EPG variability analysis shows that /ʎ/ (mean 6.2, SD 1.78, range 3.5 - 9.03) is more variable than /ɲ/ (mean 5.79, SD 2.36, range 2.78 - 9.64). Figure 5 shows that /ʎ/ is more variable in four speakers (F1, F2, F3, M1), while /ɲ/ is more variable in two speakers (M2 and M3). The difference in variability between /ʎ/ and /ɲ/ is statistically significant ($F(1, 5)=20.767$, $p<0.001$), but the interaction analysis also returns significant level of difference ($F(1, 5)=87.197$, $p<0.001$), showing that the difference in variability between /ʎ/ and /ɲ/ is different in different speakers.

Figure 5: EPG variability measure in /ʎ/ and /ɲ/ calculated for each speaker.



4. DISCUSSION

The results of the relative contact placement analysis using the CoG measure show that /ʎ/ is consistently more fronted than /ɲ/ in all speakers. This does not necessarily mean that these two sounds should be assigned two different places of articulation, because the actual difference in CoG is very small and the statistical analysis suggests that the difference in CoG is not significant in each speaker. Slightly more fronted articulation of /ʎ/ than /ɲ/ is expected, because the tongue body in /ʎ/ is more fronted so that the lateral escape of the air is allowed at postpalatal zone [11, 12].

EPG contact at five equally spaced sample points during the whole annotation (in alveolar, postalveolar and palatal zones) reveal articulatory characteristics of /ʎ/ and /ɲ/ in the temporal domain. According to the criteria defined in the introduction, the results show that none of the speakers produce these sounds as purely palatal. This is in contrast with the current classification of these sounds in the IPA [5] and in Croatian classifications [2, 6, 14]. Speaker M3's production of /ɲ/ comes closest to an exclusively palatal production, but it is still produced across at least two traditional places of articulation.

Data for /ʎ/ show that all speakers produce this sound at more than one traditional place of articulation. At least three speakers (F3, M2, M3) produce this sound as alveolopalatal, because the amount of contact in all three articulatory zones occurs at similar times, thus revealing a non-complex articulatory gesture [11, 13]. F1's, M1's and F2's trendlines could be interpreted as evidence of a quasi-independent control of the tongue front and the tongue dorsum (relative decrease of alveolar contact at the end of the annotation). Their articulations could therefore potentially be described as complex, which, in this case, would classify them as palatalized (dento)alveolars [13].

Data for /ɲ/ also show that all speakers produce this sound with similar tongue-to-palate contact at more than one traditional place of articulation. According to the criteria set out in the introduction, at least two speakers (M2, M3) produce this sound as alveolopalatal. Productions from other four speakers (F1, F2, F3, M1) could potentially be described as palatalized (dento)alveolars, because the decrease of alveolar contact towards the end of the duration could be interpreted as a sign of a complex articulation.

However, relatively early decrease of alveolar contact during productions of /ʎ/ and /ɲ/ need not be the sign of a complex articulation. Alveolopalatal productions could also exhibit slight decrease in the alveolar contact towards the end of their duration [13]. Therefore, all productions investigated here could be classified as alveolopalatal.

The analysis of EPG variability shows that /ʎ/ is more variable than /ɲ/ and that this is not consistent across speakers. Increased variability in /ʎ/ is expected, because it's more fronted articulation allows the tongue dorsum to coarticulate more than in the production of /ɲ/ [11, 12].

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