CONTINUANCY IN NASAL PLACE ASSIMILATION: AN ELECTROPALATOGRAPHIC STUDY

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ABSTRACT

Recent phonological studies suggested on purely formal (rule-based) grounds that in Croatian, an underlying alveolar nasal /n/ assimilates in place as well as in continuancy to velar obstruents /k, g, x/, but so far this claim has not been verified experimentally. Thus, in this study, electropalatography (EPG) was used in order to investigate tongue-to-palate contact patterns during the production of Croatian alveolar nasal + velar obstruent clusters. Five native Croatian speakers were recorded while producing seven distinct utterances containing the relevant clusters for six times each. The differences between assimilation conditions (/nx/ vs. /nk/ and /ng/) were tested using Repeated Measures ANOVA. The results showed that nasal place assimilation is consistently present in all examined speakers and that it is generally coupled with continuancy assimilation: underlying /n/ surfaces as a continuant [ŋ̞] before /x/ and as a non-continuant [ŋ] before /k/ and /g/. Implications of these results for phonological theory are considered and ways to obviate the limitations of the present study are discussed.

Keywords: continuancy, nasal place assimilation, nasal velar continuant, electropalatography (EPG).

1. INTRODUCTION

Phonological and phonetic descriptions of Croatian nasal place assimilation [1, 5, 9, 10, 11] report that each of the three underlying nasals behaves differently with respect to place assimilation: /n/ assimilates to bilabials, labiodentals and velars (1); /m/ assimilates only to labiodentals (2); /ɲ/ does not assimilate (3).

(1) /n/-assimilation
a. /jeda**n**-put/ → [jeda**m**put] ‘once’
b. /t͡ʃi**n**-b-en-ik/ → [t͡ʃi**m**benik] ‘factor’
c. /o**n** prat-i/ → [o**m**prati] ‘he follows’
d. /i**n**ʋalid/ → [i**ɱ**ʋalid] ‘invalid’
e. /o**n** ʋid-i/ → [o**ɱ**ʋidi] ‘he sees’
f. /ko**n**-form-iz-am/ → [ko**ɱ**formizam] ‘conformity’
g. /ba**n**k-a/ → [ba**ŋ**ka] ‘bank’
h. /ko**n**gres/ → [ko**ŋ**gres] ‘congress’
i. /i**n**xibir-a-ti/ → [i**ŋ**xibirati] ‘to inhibit’

(2) /m/-assimilation
a. /tra**m**ʋaj/ → [tra**ɱ**ʋaj] ‘tram’
b. /a**m**for-a/ → [a**ɱ**fora] ‘amphora’
c. /pita**m** ʋas/ → [pita**ɱ**ʋas] ‘I am asking you’
d. (/izni**m**-k-a/ → [izni**m**ka] ‘exception’; *[izni**ŋ**ka])
e. (/ka**m**p/ → [ka**m**p] ‘camp’)

(3) absence of /ɲ/-assimilation
a. (/ko**ɲ** bi/ → [ko**ɲ**bi] ‘horse would’; *[ko**m**bi])
b. (/ʋo**ɲ** te mut͡ʃ-i/ → [ʋo**ɲ**te mut͡ʃi] ‘the smell bothers you’; *[ʋo**n**te mut͡ʃi])
c. (sa**ɲ**k-e → [sa**ɲ**ke] ‘sled’; *[sa**ŋ**ke])

The symbol ‘-’ denotes a morpheme boundary within a word, and a blank space denotes a boundary between words. Croatian nasal place assimilation is active across both of these boundaries. In (2d–e) and (3a–c) the bracketed examples show the absence of place assimilation in certain contexts: /m/ surfaces unchanged before bilabials and velars, and /ɲ/ surfaces unchanged in all contexts.

A recent phonological study [12] suggested that in certain cases nasals assimilate in continuancy as well as in place, arguing for the necessity of the following implicational relationship: If /n/ assimilates in place to bilabial and labiodental consonants (i.e., if it changes to [m] and [ɱ] in their respective contexts), and if /n/ assimilates in place to velar obstruents (i.e., if it changes to [ŋ]), then /n/ assimilates differently to /k, g/ than to /x/. While the alveolar nasal becomes velar before all three Croatian velar segments, the alveolar nasal remains non-continuant before stops /k, g/, but it becomes continuant before the fricative /x/. The reason for proposing this implicational relationship is that the only applicable phonological feature that discriminates between bilabial and labiodental places is the manner feature [±CONTINUANT], whereby [+CONT] implies that the airflow through the oral cavity is not completely blocked, while [–CONT] implies that the airflow through the oral cavity is completely blocked [2]. Thus a phonological rule (shown in (4)) that accounts for the assimilatory pattern of the Croatian /n/ at the two labial places necessarily relies on the feature [±CONT], and, crucially, this inclusion of [±CONT] in the rule has ineluctable repercussions for the way /n/ assimilates at the velar place. In the study [12], various representational formats (e.g., multiple forms of Feature Geometry [3, 8], especially [6]) and operational architectures (e.g., Optimality Theory [7], a constraint-based phonology) were considered and discarded due to their inability to account for the empirical facts. Ultimately, the only extant framework powerful enough to account for these alternations was a rule-based phonology that treats segments as unstructured feature sets [12, 13].

(4) The rule of Croatian /n/-assimilation
/+COR, +NAS/ → [–COR, αANT, βBACK, γCONT] / __ [–COR, αANT, βBACK, γCONT]

The account of the coupling of continuancy assimilation and place assimilation presented above stems solely from a formal phonological analysis, i.e., it is a direct, automatic consequence of strictly adhering to distinctive feature theory in a rule-based framework. Even though somewhat similar phenomena had previously been noted in other languages [20, 21, 22, 23], this account has not been empirically verified for Croatian.

Electropalatography (EPG) is well suited for investigating and empirically verifying the role of continuancy assimilation in nasal place assimilation because it is the only instrumental physiological technique that provides information on the tongue-to-palate contact patterns during speech [4]. Thus, our aim is to use EPG to investigate tongue-to-palate contact patterns during the production of Croatian [ŋx], [ŋk] and [ŋg] clusters derived by rule (4). The purpose of this investigation is to test experimentally the claim—proposed on formal phonological grounds—that in Croatian nasal place assimilation is coupled with continuancy assimilation [12, 13]. If continuancy assimilation does occur, then we expect to find an incomplete velar closure during the production of the nasal in a [ŋx] cluster, and a complete or near complete velar closure during the production of the nasal in [ŋk] and [ŋg] clusters.

2. METHOD

2.1. Participants and speech material

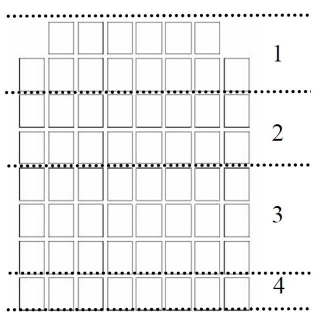
Five typical speakers (three females, two males) of Standard Croatian ranging in age between 21 and 25 took part in this investigation. Their speech was rated by five trained phoneticians as the best representative of the Standard Croatian speech among 105 candidates.

The speech material consisted of seven carrier sentences which contained seven Croatian words with an underlying *alveolar nasal* + *non-nasal velar obstruent* cluster: three words with /n/ + /x/ and four words with /n/ + /k/ or /g/ (e.g. /inxibirati/ ‘to inhibit’, /tanke/ ‘thin FEM. PL.’, /kongres/ ‘congress’). Each speaker repeated the list of sentences six times, which resulted in 210 items for the analysis.

2.2. Instrumentation and data preparation

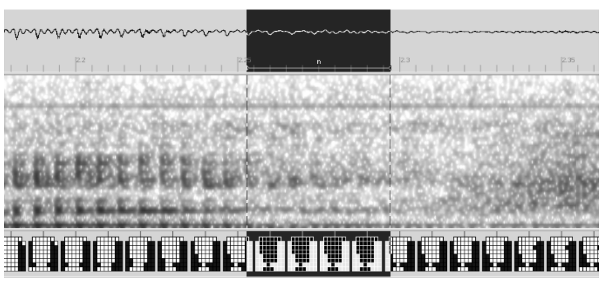
EPG and acoustic signals were recorded simultaneously. EPG data was recorded using the WinEPG system and the Reading palate (Fig 1) with the sampling rate set at 100 Hz. The acoustic data were sampled at 44100 Hz using M-Audio MobilePre external USB sound card/pre-amplifier.

Figure 1. Articulatory zoning scheme for the Reading palate: 1 – alveolar, 2 – postalveolar, 3 – palatal, 4 – velar (adapted from [17]).



Annotation and segmentation were performed according to established acoustic criteria [15, 16]. The acoustic cue for the start of the nasal was the drop in the acoustic energy at high frequencies as well as the intensity and frequency discontinuity at the vowel-nasal boundary, while the end of the nasal was marked at the point where evidence of fundamental frequency was no longer visible and frication noise or occlusion silence began (Fig 2). Data were sampled at the nasal’s mid-point.

Figure 2. An example of the application of the criteria [15, 16] used to segment and annotate the nasal.



2.3. Data analysis

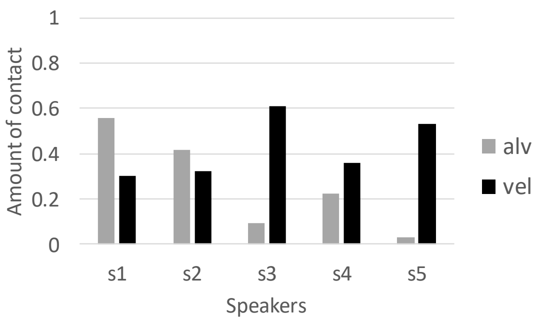
Data annotation, preparation and analysis were performed in the Articulate Assistant software [17], while data visualization was done in MS Excel. Two EPG indices were measured for each nasal token: 1. The amount of contact in the alveolar zone measured the number of contacted electrodes in the alveolar zone as a fraction of the total number of electrodes in that zone (14); 2. The amount of contact in the velar zone measured the number of contacted electrodes in the velar zone as a fraction of the total number of electrodes in that zone (8).

Variability was calculated for both of these measures by dividing the standard deviation by the mean and multiplying the result by 100 in order to express it as a percentage. The amount of contact in each row of electrodes was also exported. Differences between different assimilation conditions were tested using Repeated Measures ANOVA.

3. RESULTS

The results of the *alveolar nasal* + *velar fricative* sequence (Fig 3) show that the average velar contact is below 50 % of electrodes (0.43, SD 0.14), while the average alveolar contact is lower (0.27, SD 0.22). Maximum alveolar contact can be observed in S1 (0.56) and the minimum can be found in S5 (0.03). Velar contact ranges between 0.30 (in S1) and 0.61 (in S3). There are noticeable inter-speaker differences in assimilatory strategies. Some speakers produce /n/ before a velar fricative with more contact in the alveolar than in the velar zone (e.g., S1), while other speakers produce /n/ before a velar fricative with an increased velar contact and very low alveolar contact (e.g. S5).

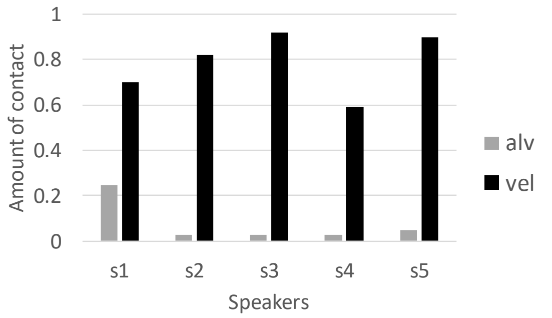
Figure 3. The amount of alveolar and velar contact in the production of the alveolar nasal followed by a velar fricative for each speaker.



There is no evidence of complete place assimilation (i.e., a total absence of the tongue-to-palate contact at the alveolar zone with some tongue-to-palate contact at the velar zone), except perhaps in S5. Crucially, the results show the absence of a full velar occlusion during /n/ in /nx/ sequences for all speakers.

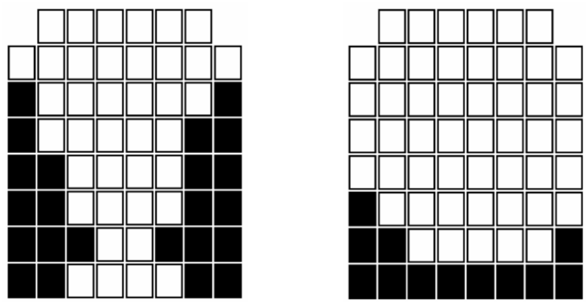
Tongue-to-palate contact in /n/ followed by a velar stop (/k/ or /g/) (Fig 4) shows that the average velar contact is almost 80% (0.79, SD 0.14) and the average alveolar contact is much lower (0.07, SD 0.09). The pattern of increased velar contact when compared to the alveolar contact can be observed in each speaker. All speakers except S1 show signs of almost complete place assimilation and at least three speakers show some indication of complete velar closure during /n/ when followed by velar stop. Velar contact ranges between 0.59 in S4 and 0.92 in S3, which shows that the lowest amount of velar contact in *nasal* + *stop* sequences almost equals the highest amount of velar contact in the *nasal* + *fricative* sequence. Alveolar contact ranges between 0.03 in S2, S3, S4 and 0.7 in S1.

Figure 4. The amount of alveolar and velar contact in the production of the alveolar nasal followed by a velar stop for each speaker.



The difference in velar contact between *nasal* + *fricative* and *nasal* + *stop* sequences is statistically significant ($F(1, 8) = 14.821$, $p = 0.018$), while the difference in alveolar contact between these two sequences is not statistically significant ($F(1, 8) = 5.741$, $p = 0.075$). Figure 5 shows a typical example of this difference at the velar region.

Figure 5. EPG images of the mid-point in S5's pronunciation of the nasal in a /nx/ cluster (left) and in a /nk/ cluster (right).



4. DISCUSSION

The purpose of this EPG investigation was to test experimentally the claim that in Croatian, nasal place assimilation is coupled with continuancy assimilation.

In all cases (summarized by Fig 3 and Fig 4), there is some tongue-to-palate contact at the velar zone during the production of the nasal before a velar, indicating that in general all speakers perform nasal place assimilation at least to some extent. Less tongue-to-palate contact at the velar zone in the nasal of the /nx/ cluster (Fig 3) compared to the nasal of the /nk/ and /ng/ clusters (Fig 4) is consistent with the tested claim: the presence of continuancy throughout the realization of /nx/ clusters results in a lesser constriction at the velum and therefore less electrode activation at the velar zone than compared to the realization of /nk/ and /ng/ clusters which contain complete or near-complete closures. It is not uncommon that EPG results show an incomplete closure for velar stops because occlusion can sometimes occur beyond the most posterior row of electrodes [19]. It is therefore not surprising that some speakers do not produce *nasal* + *stop* sequences with electrode activation across the entire velar zone. Nevertheless, the majority of speakers show more velar contact in *nasal* + *stop* sequences than in *nasal* + *fricative* sequences.

Also clear from the results in Fig 3 is that speakers S1 and S2 employ different assimilatory strategies from S3, S4 and S5 insofar as S1 and S2 produce a substantial tongue-to-palate contact at the alveolar zone. The retention of this contact at the alveolar zone in S1 and S2 (as opposed to its relative absence in S3, S4 and S5) can most plausibly be explained by appeal to extra-grammatical factors: the relative infrequency of the words containing /nx/ clusters coupled with the latent orthoepic norm of Standard Croatian [10] leads S1 and S2 to superimpose certain functional factors (e.g., hyperarticulation) over the effects of rule (4). A further complicating factor might be individual anatomical and physiological differences in vocal apparatuses which lead speakers to adopt different production strategies [18]. However, the presence of the effects of rule (4) is clear from the fact that speakers S1 and S2 still consistently produce a 30–35 % contact at the velum.

The same reasoning can also be extended to account for the apparent lack of categoricality in assimilatory patterns: the interplay of categorical mental (phonological) operations and functional factors during speech—such as inconsistently hyperarticulating less common words in order to conform to an equivocal orthoepic norm of a standard language—naturally leads to the EPG data leaving the impression of absence of categoricality (and of recalcitrancy in general) which is more prominent in some speakers (S1, S2 and maybe S4) than in others (S3 and especially S5).

The results show that nasal place assimilation indeed is consistently coupled with continuancy assimilation: the underlying alveolar nasal stop /n/ (–CONT) is realized as a velar (or at least velarized) nasal continuant (+CONT) before a velar fricative /x/ (+CONT); the underlying alveolar nasal stop /n/ (–CONT) is realized as a velar nasal stop (–CONT) before velar stops /k/ and /g/ (–CONT). This is corroborated by the statistically significant ($F(1, 8) = 14.821$, $p = 0.018$) difference in the electrode activation at the velar zone between *nasal* + *fricative* vs. *nasal* + *stop* sequences. However, two cautionary caveats are in order due to methodological limitations. First, the number of participants in the EPG experiment (5 native speakers) might not be sufficient for reaching definitive conclusions. Second, an intrinsic shortcoming of EPG is that for physiological reasons the velar zone is not entirely covered by electrodes, therefore it is possible that some data relevant for the research question of this study were not taken into account. In future studies, these limitations could be overcome by including additional participants and employing other kinematic techniques such as ultrasound.

To summarize, using EPG, this study showed that in Croatian, nasal place assimilation is generally coupled with continuancy assimilation: underlying /n/ surfaces as a continuant [ŋ̞] before /x/ and as a non-continuant [ŋ] before /k/ and /g/. It was argued that the coupled place and continuancy assimilation of /n/ before velar obstruents is driven by the phonological rule (4), while the sporadic retention of the original tongue-to-palate contact at the alveolar zone (Fig 3) was attributed to extra-grammatical functional factors superimposed on the effect of rule (4).

5. ACKNOWLEDGEMENTS

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