Anticipatory Coarticulation in a Specific Context

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Abstract

In Hungarian casual speech, [n] may not be fully pronounced before continuant consonants. In this paper the durational changes of the vowel and the nasal as well as the formants of the vowel were analyzed in VNC sequences. The spreading coarticulatory effect in these sequences is supposed to originate from the continuant C (fricatives and approximants) that modifies the [n] articulation. The results show that there is a strong spreading anticipatory coarticulation leading to significant changes in the duration of the vowels and the nasals preceding fricatives and approximants. The coarticulation affects the F2-value of the vowel as well.

1 Introduction

Speech is produced as a sequence of sounds as the vocal tract moves from one articulatory configuration to the next. Coarticulation refers to the transition from one gesture to another whereby the different articulation gestures combine with different timing patterns [2, 3]. Research has shown the existence of various nasalization effects in VowelNasalConsonant sequences across languages [1, 5], while less attention has been paid to compensatory lengthening in the vowels in such sequences depending on the type (continuant vs. non-continuant) of the consonant following the nasal sound [4]. In this study spreading anticipatory coarticulation in Hungarian was analyzed in the sequences

$$V^{[\text{ɔ}]}_{[\text{ɛ}]} + C_1^{[n]} + C_2 \begin{matrix} [\text{t,d,ts,tʃ}] \\ {[\text{s,z,ʃ,ʒ}]} \\ {[\text{l,j}]} \end{matrix}$$

The vowels are followed by the dento-alveolar nasal sound and the post-nasal C which is either an obstruent (stop, fricative or affricate) or an approximant. In Hungarian casual speech, /n/ may not be fully pronounced before continuant fricatives and approximants [6]. Closure for the nasal may be incomplete, resulting in a shorter nasal sound and in this case the preceding vowel is lengthened. Neither the modified articulation of the nasal, nor compensatory lengthening in the preceding vowel takes place before non-continuant stops and affricates. The spreading coarticulatory effect in the VNC sequences is supposed to originate from the continuant C that modifies the [n] articulation. Our hypothesis is that the modified nasal affects not only the duration but also the formant frequencies of the preceding vowels. We also suppose that both the fricatives and the approximants will affect the preceding sounds in the analyzed VNC sequences. The goal of the present research was to show the acoustic-phonetic consequences of spreading anticipatory coarticulation in terms of nasal duration and the duration and formant frequencies of the preceding vowels.

2 Subjects, material, method

Ten native female speakers of Hungarian with no known speech or hearing defects read randomized isolated words and phrases in a sound-proofed chamber (ages ranged from 20 to 28).

The word list consisted of 20 Hungarian words and phrases that contain the dento-alveolar nasal [n] followed by either a fricative, or a stop/affricate or an approximant. The VN cluster belonged to the first syllable in all of the words, while the second syllable started with the other consonant as in the word *kAN/Dúr* ('tomcat'). The [ɛ] and [ɔ] vowels were chosen to precede the nasal sound because they have no phonologically long counterparts, on the one hand, and they are the most frequent vowels in Hungarian, on the other hand. Examples: *kancsal* ('cross-eyed'), *hentes* ('butcher'), *lenzsák* ('flax bag'), *tanszék* ('department'), *kancát* ('mare' +Acc.), *lencsét* ('lentil'+Acc.), *fenség* ('majesty').

The words were recorded in a sound tight chamber and digitalized up to 44,000 Hz. Acoustic-phonetic analysis was carried out by Praat software, version 5.4. The nasal [n], the previous vowel, and the following consonant were identified in each word for each speaker. The duration of the nasal consonant and of the preceding vowel, as well as of the first three formants of the vowels were measured. The duration of the vowels was measured as the interval from the second formant onset to the onset of the nasal formants. The corresponding spectrographic and waveform displays were consulted and auditory perception was also considered. Nasal duration was measured to the onset of the obstruent consonant and to the onset of the second formant of the approximant (Fig. 1.) The formant structure of the vowels was measured by means of the series of frequency values measured in every 0.006 ms of the total duration of the vowel. The formant values were normalized. This method provided an opportunity to analyze the tendency of changes in frequency patterns for the whole duration of the vowel. Statistical analysis of the data was carried out using ANOVA and regression analysis (using SPSS 14.0). In all cases, the confidence level was set at the conventional 95%.

3 Results

Acoustic-phonetic analysis confirmed our expectation that spreading anticipatory coarticulation appears in VNC sequences. Continuant obstruents and approximants affect the duration of nasals, making them shorter compared to nasals preceding non-continuant obstruents. The temporally modified (shortened) nasal has a twofold effect on the preceding vowel: (i) the vowel is lengthened, and (ii) its second formant frequencies will be different from those preceding nasals followed by non-continuants.

3.1 Coarticulation effects on the nasal

The acoustic structures of the nasal [n] preceding continuants and non-continuant s can be clearly seen in the examples shown in Figure 1. The nasal sounds are relatively longer before stops and affricates than before fricatives and approximants (Fig. 2). The mean duration of [n] before non-continuants is 104.95 ms (SD=23.75), 59.55 ms (SD=25.74) before continuants, and 81.91 ms (SD=18.36) before approximants. The statistical analysis showed significant differences in nasal durations depending on the type of the following consonant (one-way ANOVA: $F(2, 199) = 114.860$, $p<0.001$). In some languages, nasals are shorter before voiceless than before voiced consonants [1]. This fact also can be seen in our data; however, it could be statistically confirmed only for stops in Hungarian. As expected, the duration of [n] is significantly shorter depending on voicing in the following stops (one-way ANOVA: $F(1, 79) = 37.994$, $p<0.001$); however, there is no such difference in the case of the following fricatives.

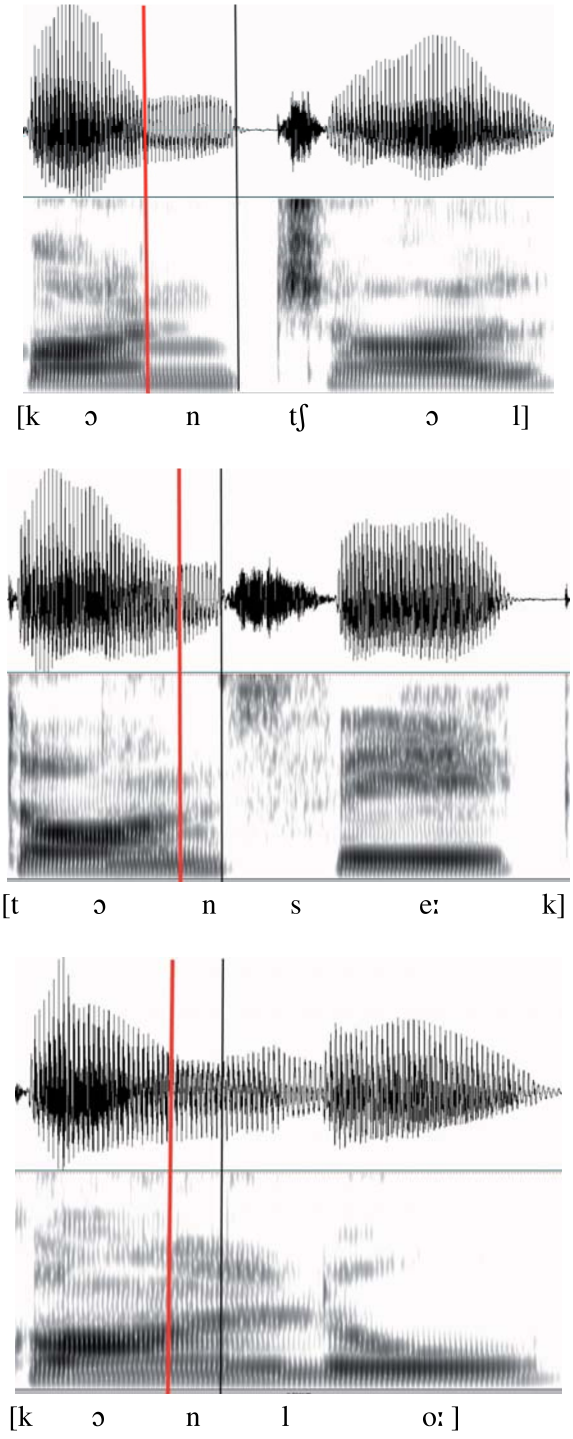

Figure 1: *The acoustic structure of the words* kancsal *('cross-eyed'),* tanszék *('department') and* kanló *('stallion')*

The mean value of the duration of [n] is 128.35 ms (SD=18.28) when followed by voiced stops and 102.35 ms (SD=16.21) when followed by a voiceless stop. The duration of the nasal also shows a tendency to become shorter before voiceless fricatives. The mean value of [n] is 63.57 ms (SD=23.99) before a voiced fricative and 56.97 ms (SD=25.92) before a voiceless fricative (one-way

ANOVA: $F(1, 79) = 1.621$, $p<0.207$). In sum, continuant obstruents affect the temporal patterns of nasal articulation while the approximants have less pronounced, but similar effects on them.

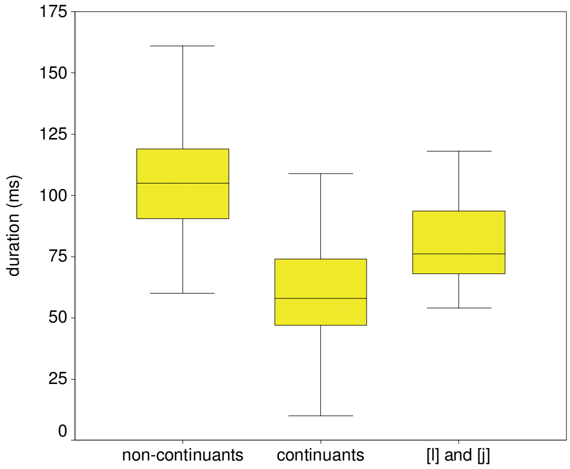

Figure 2: *Durational data of the nasal* [n] *as a function of the following consonant (median and range)*

The nasal consonant shows some stability before non-continuants (stops and affricates) which means that the nasal preserves the closure in its articulation. Therefore the duration of the nasal is longer. The [n] is less stable before fricatives. In these cases the articulation of the nasal is characterized by an early onset of the velum gesture and by the lack of closure. The blade of the tongue approaches the alveolar ridge but never reaches it. This "irregular" articulation gesture that does not obstruct the airflow in the vocal tract results in a shortened nasal. This may be regarded as an anticipatory coarticulation effect of continuants. Since fricatives and the [l] and [j] sounds share the same „friction" gesture in their articulation, approximants may be expected to show a similar coarticulatory effect. Indeed, the durational data confirmed that, although approximants seem to form a separate category in respect of coarticulatory effect, the duration of the nasal before approximants is very similar to that before continuant obstruents.

3.2 Coarticulation effects on vowels

The duration of the vowels preceding the nasal sound was expected to be longer before continuants than before non-continuants. The duration of both the analyzed vowels was the longest when the nasal is followed by a continuant obstruent (for [ɔ]: mean = 158.5 ms, SD=29.74; for [ɛ]: mean = 178.7 ms, SD=18.91). A shorter duration was found when the nasal was followed by the approximants (for [ɔ]: mean = 146.3 ms, SD=25.46; for [ɛ]: mean = 161.05 ms, SD=22.62). The shortest duration was found when the nasal was followed by non-continuants (for [ɔ]: mean = 132.1 ms, SD=15.20; for [ɛ]: mean = 135.4 ms, SD=28.00), cf. Fig. 3. Statistical analysis proved that there was a significant difference in durations depending on the three consonant types (one-way ANOVA for [ɔ]: $F(2, 79) = 10.855$, $p<0.001$ and for [ɛ]: $F(2, 79) = 33.734$, $p<0.001$).

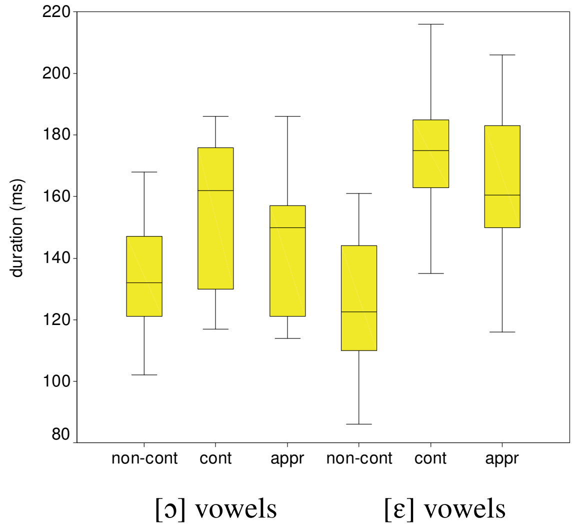

Figure 3: *Durational data for the vowels* [ɔ] *and* [ɛ] *in various VNC contexts (median and range)*

It was hypothesized that in addition to durational changes, the formant structure of the vowels would also be affected depending on the type of the consonant following the nasal in the sequence. The data in Table 1 show that there are no great differences in the first and third formant values of the vowels depending on continuancy or non-continuancy of the obstruents or approximants. The F2 values of the vowels, however, show significant differences, depending on the consonant that follows the nasal (one-way ANOVA for [ɔ]: $F(2, 2165) = 66.728$, $p<0.001$ and for [ɛ]: $F(2, 2022) = 39.116$, $p<0.001$). The post-hoc Tukey test confirmed significant differences for all the consonants studied. Continuant obstruents and approximants have the same, while non-continuant obstruents have different effects on the vowels.

The mathematical functions applied also support the finding that the type of C in VNC sequences results in different coarticulatory effects. Figure 4 shows the values of the second formants in the time course of the [ɔ] vowels in the words *tanszék* ('department') and *kancsal* ('cross-eyed').

Table 1. *Mean values of F1, F2 and F3 for the vowels preceding the nasal.*

F	C	[ɔ]		[ɛ]	
		mean (Hz)	SD	mean (Hz)	SD
F1	non-cont.	712.8	149.9	670.1	115.3
	cont.	673.9	183.7	645.7	133.0
	appr.	756.2	143.4	632.0	116.1
F2	non-cont.	1322.2	207.7	1891.7	277.6
	cont	1387.4	223.4	1839.7	247.6
	appr.	1474.4	202.1	1984.0	302.4
F3	non-cont.	2630.9	357.1	2758.8	417.8
	cont.	2640.6	429.0	2762.3	426.8
	appr.	2664.7	419.4	2814.4	305.0

Abbreviations: F – formants, C – consonants following the nasal, non-cont. – non-continuants, cont. – continuants, appr. – approximants

A linear function was applied to the F2-values in cases where C was either a stop or an affricate, and a polynomial function was used where C was either a fricative or an approximant (an example for the latter is *kanló* /'stallion'/: $y=0.9052x^2 - 19.997x + 1038.8$, $R^2 = 0.9551$).

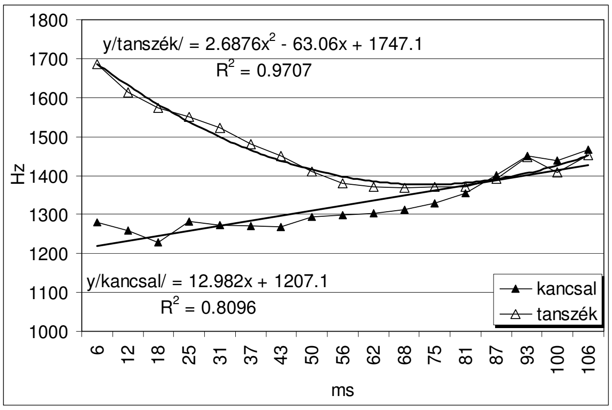

Figure 4: *Functions applied to the F2-values for two Hungarian words*

4 Conclusions

Analysis of the durational patterns of nasals and vowels in VNC sequences raises the question whether what has so far been regarded as compensatory lengthening is rather a compensatory shift within the vowel+nasal combination. In this case the total duration of the combination should be reasonably stable. Our data show that the total durations of [ɔn] and [ɛn] sequences, independently of vowel quality and type of obstruent following the nasal, show very similar values, amounting to about 236 ms. The durations of VN sequences followed by approximants show similar values at 221 ms vs. 243 ms (Table 2). Thus, vowel lengthening as a spreading coarticulatory effect in the VNC sequence can be viewed as a coarticulatory shift within the VN combination.

Table 2. *Total duration of VN combinations.*

Data (ms)	[ɔ] + [n]		[ɛ] + [n]	
	obstruent	[l, j]	obstruent	[l, j]
Mean	236.68	221.7	236.2	243.3
SD	18.19	25.2	19.9	33.9

Spreading anticipatory coarticulation works across syllable boundaries in Hungarian. It first affects the nasal's duration, and then it exerts an effect on the duration and the second formant of the preceding vowel. The tongue body's raising or lowering gesture seems to have an impact on F2. The effect of the voiced stop consonants is manifested in a significantly longer duration of the nasal compared to that of voiceless stops. However, this is not the case with fricative consonants. The coarticulatory effect was also confirmed for the approximants: this appeared to be more similar to that caused by continuant obstruents than by non-continuants. This research showed the existence of a strong spreading anticipatory coarticulation process resulting in the modification of the articulation of vowels and nasals preceding fricatives and approximants. The issue of anticipatory behavior is crucial for the understanding of speech production. The present results reflect the domain over which the motor system organizes VNC sequences of articulation.

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