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Coarticulatory Effects of Vowel Quality on Velar Function[1]

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Abstract. Velar elevation data were collected for 12 utterance pairs contrasting in vowel quality. It is well-known that velar position for any phonetic segment is determined by at least two factors: the nature of the segment itself and the phonetic environment in which the segment occurs. Thus, velar elevation increases through the series of segment types: nasals, open vowels, close vowels, obstruents; and velar elevation for English vowels is affected by adjacent nasals. In these data, vowel quality was found to affect velar position during adjacent consonants: that is, the velum was lower for both nasals and obstruents in an environment of open vowels than in an environment of close vowels.

Introduction

It has long been known [HILTON, 1836; BIDDER, 1838; PASSAVANT, 1863; CZERMAK, 1869] that the position of the velum differs for different oral segments, these differences being the nature of the segment itself and of its phonetic environment. Generally, velar height differences associated with the segment vary directly with the oral cavity constriction of the segment, increasing through the series: open vowels-close vowels-obstruents [for example: CZERMAK, 1869; MOLL, 1962; BZOCH, 1968; LUBKER, 1968; FRITZELL, 1969; BELL-BERTI and HIROSE, 1975]. The influence of phonetic environment on velar position is exemplified by the effect of nasals on adjacent vowels. Velar elevation for English vowels is affected by adjacent nasals, so that the velum is lower for vowels preceding nasal than for vowels preceding obstruent conso-

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nants. Similarly, the velum is frequently lower for English vowels when they immediately follow nasal consonants than when they follow obstruent consonants.

Although the effect of neighboring nasal and obstruent consonants in modifying the velar elevation for vowels is well known, the opposite effect has not been studied. Therefore, in this paper, we examine the effects of vowel type on velar position during adjacent nasal and obstruent consonant segments.

Method

A native speaker of standard Greater Metropolitan New York City English (one of the authors of this paper) served as the subject for this study. An inventory of 24 two-syllable nonsense words, each beginning with /f/ and ending with /p/, was used in the experiment. The same vowel occurred in both syllables, and was either /i/ or /a/. Two consonants, one a nasal (/m/), the other one of six obstruents (/p, b, f, v, s, z/), occurred between the vowels in all possible combinations (table I). The utterances were placed in lists in random order, and the lists were read from 6 to 10 times.

A long thin plastic strip with grid markings was inserted into the subject's nostril and placed along the floor of the nose and over the nasal surface of the velum, to enhance the contrast between the edge of the supravelar surface and the posterior pharyngeal wall (fig. 1). A flexible fiberoptic endoscope (Olympus VF Type O) was also inserted into the subject's nostril, and was positioned so that it rested on the floor of the nasal cavity with its objective lens at the posterior border of the hard palate, providing a view of the velum and lateral nasopharyngeal walls, from the level of the hard palate to above the maximum elevation of the velum (observed during blowing). The position of the high point of the

Table I. Experimental utterances

	Oral/nasal	Nasal/oral
	fipmip	fimpip
	fibmip	fimbip
V = /i/	fifmip	fimfip
	fivmip	fimvip
	fismip	fimsip
	fizmip	fimzip
	fapmap	fampap
	fabmap	fambap
V = /a/	fafmap	famfap
	favmap	famvap
	fasmap	famsap
	fazmap	famzap

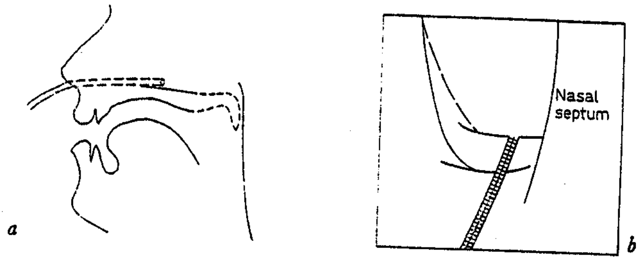

Fig. 1. Schematic representation of: placement of the fiberoptic endoscope in the subject's nose (a) and view of the nasopharynx, with the grid in place, seen through the fiberscope (b). The solid line contour represents the view when the velum is low; the dashed-line contour represents the view when the velum is slightly elevated.

velum was then tracked, frame-by-frame, with the aid of a small laboratory computer[3]. The measurements of velar elevation for the tokens of each utterance type were aligned with reference to the acoustic boundary between the nasal and obstruent consonant, and frame-by-frame ensemble averages calculated.

Acoustic segment durations of the vowels and medial consonants were also measured, from digitized waveforms of the speech samples. Average segment durations are displayed beneath the velar height plots of figures 2–4.

Results

First, inspecting the data for confirmation of previous observations, we find, as expected, that relative velar elevation increases through the series of oral segments: open vowels-close vowels-obstruents (fig. 2a), confirming the results of earlier studies [for example, Moll, 1962; Lubker, 1968; Fritzell, 1969; Bell-Berti and Hirose, 1975]. In addition, vowels preceding nasals showed the expected anticipatory effects – that is, the velum was lower during those vowels than during the same vowels in an oral environment (fig. 2b). Similarly, carryover effects are seen in vowels following nasals. The velum was lower during a vowel following a nasal than during the same vowel following an oral

[3] Although the grid makes it possible to determine the distance between the lens and the velar high point, and, therefore, the absolute height at that point, we have not done so. Instead, we have described differences in velar position in arbitrary units that are linear on the projected image, but that do not represent equal units of elevation. We believe our data are valid in spite of this nonlinearity because the effect of using a flat-projection reference minimizes the most extreme elevations, which occur furthest from the objective lens. Thus, the differences in maximum elevation would be more pronounced if we calculated absolute velar elevation.

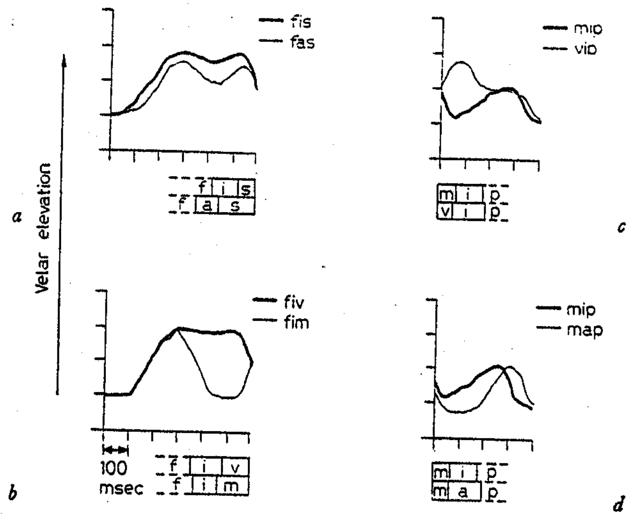

Fig. 2. Plots of average velar elevation, in arbitrary units as a function of time. Average segment durations are indicated beneath each graph.

consonant (fig. 2c). Finally, we also see that the velum was elevated sooner and more rapidly for a high vowel than for a low vowel, following a nasal consonant (fig. 2d).

Returning to the subject of this study, the influence of vowel quality on velar elevation for consonant segments, we find that velar height for the vowel generally affected both nasal and oral consonants in the same utterance (fig. 3). The velum was higher throughout utterances containing /i/ than utterances containing /a/ in 10 of 12 possible comparisons[4]. In order to clarify this effect, the data were pooled across consonant type, and an ensemble average was computed for each of the utterance types /fiCmip/, /faCmap/, /fimCip/, and /famCap/ (fig. 4). It can be seen that the overall pattern for /i/ and /a/ utterances is similar. We have no final explanation for the contrast in magnitude of differences for 'nasal-first' and 'oral-first' averages, though we suspect that syllable-stress may be involved.

[4] These two comparisons were /fizmip-fazmap/ and /fifmip-fafmap/. It seems unlikely that the failure of the pattern to persist through these two comparisons is due to the particular oral consonants in those items for two reasons. First, the initial /f/ also fails in these items, and in no others. Second, the comparison succeeds during these same consonants in the nasal/oral contrasts.

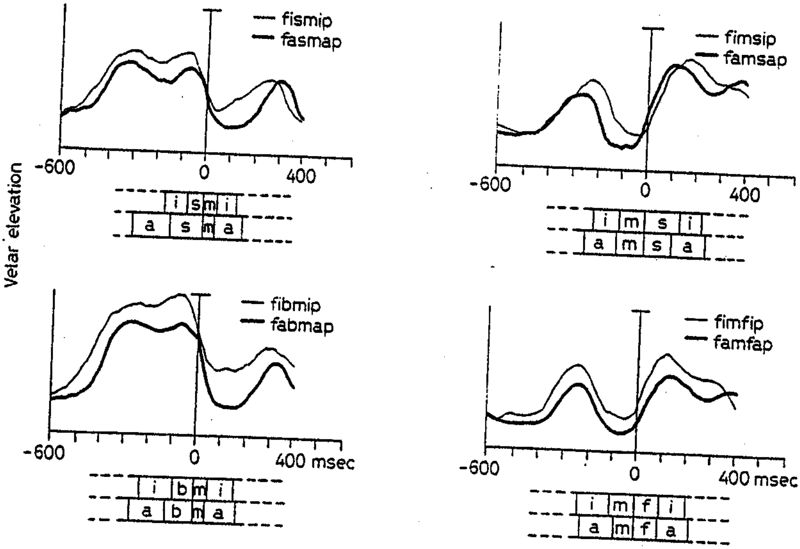

Fig. 3. Plots of average velar elevation, in arbitrary units as a function of time, for utterance pairs of contrasting vowel quality. Utterances having a medial oral/nasal consonant contrast are at the left; those having a medial nasal/oral consonant contrast are at the right.

Discussion

These results may be explained in several ways. One possibility is that the acoustic requirements for consonants might differ in different environments. For example, if velopharyngeal closure is incomplete during production of an obstruent consonant, different port sizes might be required to prevent nasal coupling when the vocal tract is shaped for /i/ than when it is shaped for /a/. This would imply that velar position must be specified differently for consonants in each vowel environment.

These data, unfortunately, do not allow us to test this hypothesis, since, in observing velar elevation we did not observe the port itself, and, therefore, we do not know at what velar elevation it closed. However, we could test the hypothesis by producing the assumed articulations using an articulatory synthesizer [Mermelstein, 1973; Cooper *et al.*, 1977], and we plan to do so.

Another interpretation of these results is that the motor plan requires that consonants be produced in association with some vowel.

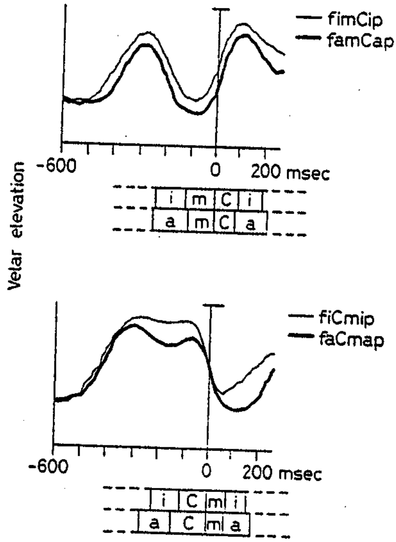

Fig. 4. Plots of average velar elevation, in arbitrary units, as a function of time, for utterance pairs of contrasting vowel quality. Data are pooled across oral consonant type. Utterances having a medial nasal/oral consonant contrast are at the top; those having a medial oral/nasal consonant contrast are at the bottom.

The models of ÖHMAN [1966] and FOWLER [1977] emphasize the importance of the properties of vowels in generating the observed characteristics of the coarticulated consonants. This view is contrasted with that found in models generating articulator position as the function of a segment-by-segment specification of feature values. In such a system, one would not expect velar position for oral consonants in VCNV environments to differ with the vowel, because velar position for the final vowel cannot be anticipated during the obstruent consonant since the intervening nasal consonant requires a markedly different velar position.

The ÖHMAN [1966] and FOWLER [1977] models differ as to the exact nature of the relationship between the vowels and consonants in a phonetic string. In ÖHMAN's model, speech is considered to be a vowel-to-vowel act, with consonants superimposed on context-dependent vowel strings. Alternatively, FOWLER's model postulates separate mechanisms for vowel and consonant articulation, with the two mechanisms activated in parallel and the segments 'coproduced'.

The current data are inadequate for differentiating between the acoustic-necessity hypothesis and the ÖHMAN, FOWLER, or other vowel-dependent hypotheses. Consequently, we are continuing our study of velar position in a variety of different vowel and consonant contexts.

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