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A. ANALYSIS OF FORMANT TRANSITIONS FOR CONSONANTS

In earlier reports we presented some results of measurements of the frequencies of the first three formants throughout the stressed vowel in each of a number of bisyllabic utterances. The utterances were of the form /hə'CVC/, where C_1 and C_2 were

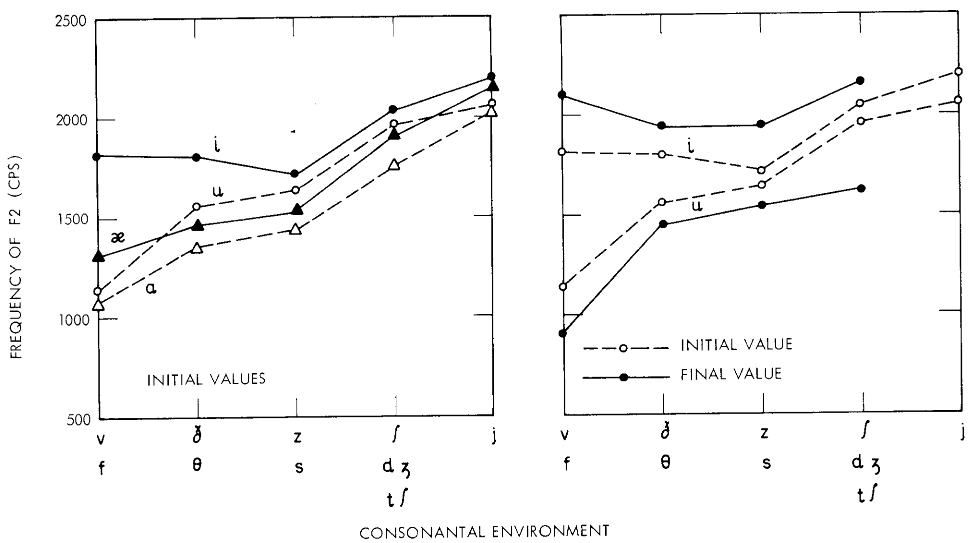

Fig. XIV-1. Average values of F_2 at the boundaries of the vocalic portions of CVC syllables for various consonants and vowels as indicated. Average values for three talkers.

the same consonantal phoneme; eight vowels and 15 consonants appeared in the materials. An analysis-by-synthesis procedure implemented on a digital computer was used

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to obtain the experimental data. The emphasis in these earlier studies was on the influence of consonantal environment on the formant frequencies at centrally located regions within the vowels.

Further analysis of these data has recently been carried out, with particular emphasis on formant frequencies at the consonant-vowel boundaries, that is, at the beginnings and ends of the vowels. Also, measurements have been obtained for stressed vowels in consonantal environments not previously studied, including some asymmetrical environments.

Examples of some of the effects that are under study are shown in Fig. XIV-1. In these graphs the frequency of the second formant at the beginnings or ends of various vowels is plotted as a function of consonantal environment. Different consonantal environments are arranged along the abscissa roughly according to place of articulation, with the most-fronted articulations to the left. All of the consonants represent symmetrical environments, except /j/, which precedes but does not follow each vowel.

The graph at the left, which gives data for four different vowels, indicates that there is, on the average, a steady increase in the initial values of F_2 as the place of articulation of the consonant is displaced from the lips to the palate. The average values are in reasonable agreement with other data on second-formant loci and with the predictions of the theory of acoustic resonators. The spread in initial values of F_2 is greatest for labial environments and least for palatal environments, in agreement with the expectation that the tongue mass is relatively free to anticipate the following vocalic articulation during the production of a labial consonant. In all consonantal environments the initial value of F_2 is least for /ɑ/ and greatest for /i/. These articulations of these vowels represent two extremes in the area of the pharyngeal portions of the vocal tract, and presumably these differences are reflected in the data at the consonant-vowel boundary.

In the right-hand graph differences between initial and final values of F_2 are shown for /i/ and /u/. Similar plots for the vowels /æ/ and /ɑ/ would demonstrate that the initial and final values are essentially the same for these vowels. In the case of the close vowel, apparently the articulation of the final consonants is closer to that of the vowel than is the consonantal articulation that precedes the vowel. This effect could be due, in part at least, to less effort or 'stress' associated with the post-vocalic consonant resulting in an articulation that shows the influence of the preceding vowel more clearly. Further examination and interpretation of these data in terms of articulatory processes is continuing.

K. N. Stevens, A. S. House

B. NOTE ON PALATALIZATION IN RUSSIAN

Previous research[1, 2] has indicated that for speakers of Swedish and American English a voiced stop in VCV context may be regarded as articulated simultaneously with and, to some extent, independently of an underlying diphthongal vowel motion. The stop consonant is thus mixed into an unbroken vowel gesture rather than concatenated with a preceding and following vowel posture.

One feature of this type of coarticulation may be observed in the variations of the formant transitions associated with the consonant. The course of these transitions in a fixed VC sequence may differ drastically, the difference depending on the F-pattern of the vowel following the stop. The explanation of this seems to be that the articulatory instructions relating to the stop and final vowel reach the vocal apparatus at approximately the same time, so that the motion toward and through the stop becomes modified in anticipation of the final vowel.

X-ray studies have shown that the defining feature of a stop in the material analyzed is its characteristic region of closure (labial, alveodental, palatovelar for /b/, /d/, and /g/, respectively), but that the actual shape of the tongue is free to assimilate the shapes of preceding and following vowels in a purely automatic fashion. To account for this it has been proposed that the group of muscles used for the production of the stop only partially overlaps with that used for any individual vowel, and that vowel and stop production is controlled over separate neural channels.

In terms of this model a stop consonant involves two components, viz., a closure gesture proper, and a vowel substrate that may cause large changes in the shape of the vocal tract even during the stop closure.

In the speech of the Swedish and American English talkers thus far studied, the shape of the vocal tract during a stop-consonant closure seems to be determined entirely by the characteristics of the initial and final vowels. The nature of the vowel substrate is an automatic and phonologically irrelevant feature of the stop in these languages. In principle, however, it could very likely be used for purposes of phonemic differentiation. This seems, in fact, to be the case in Russian.

In Russian the well-known feature of palatalization cuts through most of the consonantal system.[3] In the palatalized members of contrasting pairs the vowel underlying the stop is invariably high-front (i-like), whereas in the unpalatalized members it approaches the high-back (ɨ-like) type. It might thus be expected that the vocal-tract shapes corresponding to the Russian voiced stops in VCV contexts which are analogous to those studied for Swedish and American English should be relatively unaffected by the characteristics of the adjacent vowels.

To test this hypothesis a small spectrographic study has been made of a set of utterances produced by a male speaker of Modern Standard Russian. The list of utterances

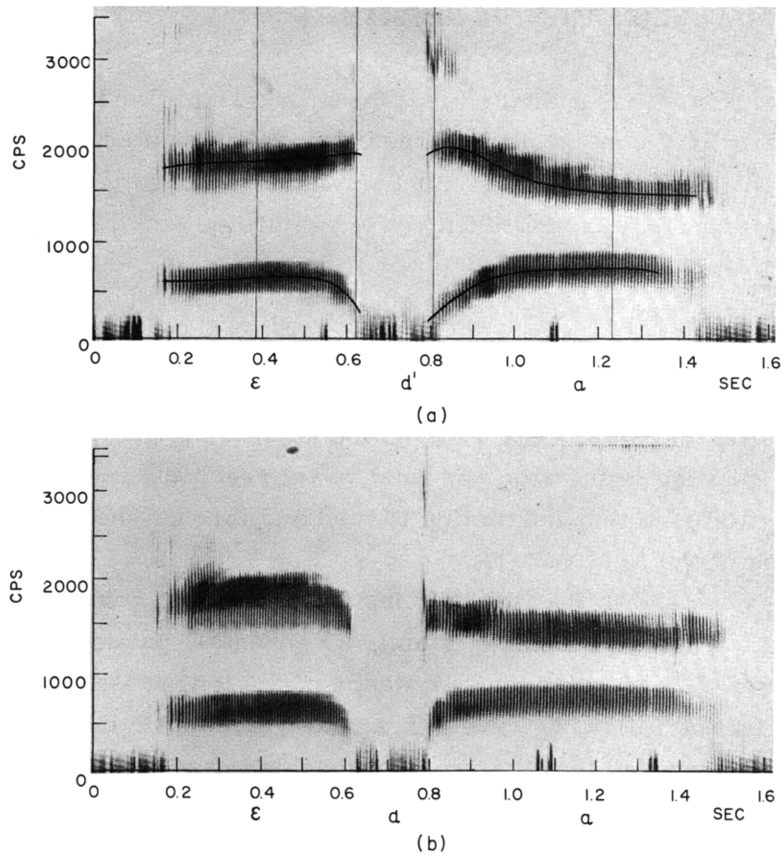

Fig. XIV-2. Sound spectrograms of the utterances /ɛd'a/ and /ɛda/. The vertical lines (a) show where the first and second formants were measured. Note the difference, resulting from palatalization, of the second formant transition of the initial vowel of the two utterances.

recorded consisted of 30 different "words" in which the initial vowel was /ɛ/, the consonant either /b'/, /b/, /d'/, /d/, /g'/, or /g/ and the final vowel either /i:ɨ/, /ɛ/, /a/, /o/, or /u/. The words were printed on cards and arranged in random order. The speaker read the words from the cards. Each word was read five times. The speaker attempted to keep his pitch on a monotone and to give both vowels of the VCV words approximately equal stress.

The measurements were made from sound spectrograms of the utterances. The first and second formant frequencies were measured in the most stationary part of the initial and final vowels. The frequency of the second formant at the boundary between the initial vowel and the stop-closure interval was also recorded. These measurements are illustrated in Fig. XIV-2.

Figure XIV-3 shows an F_1 vs F_2 plot of the final vowels. The filled circles represent vowels following palatalized stops, and the open circles represent vowels following

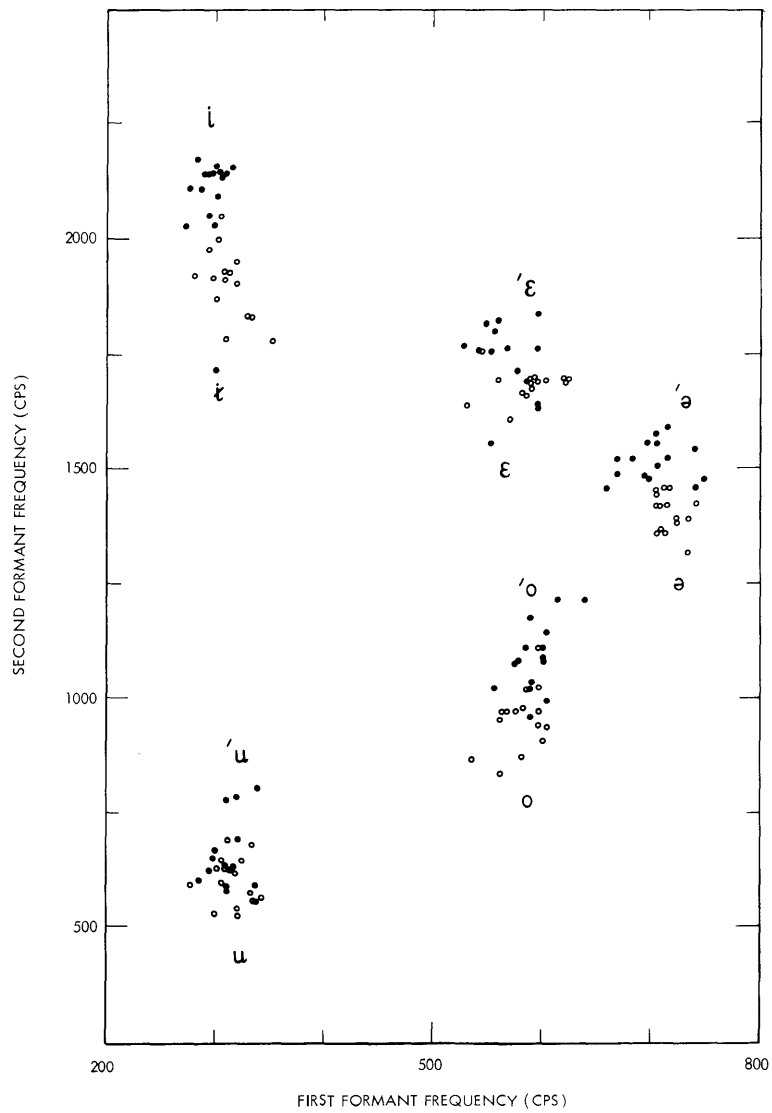

Fig. XIV-3. F_1 vs F_2 plot of the final vowels of the word material studied. The filled circles indicate vowels following palatized consonants and the open circles indicate vowels following unpalatalized consonants.

unpalatalized stops. The vowels of the latter set apparently have a somewhat lower F_2 than the corresponding vowels of the former set.

Table XIV-1 presents the mean values – computed over each group of five readings – of the difference between the F_2 terminal and stationary frequencies of the initial vowel of each word. This difference is positive when the formant points upward and negative when it points downward. All numbers have been rounded off to the nearest 25 cps. The mean stationary first- and second-formant frequencies of the initial vowel (/ε/) were

Table XIV-1. Average differences in cps between the terminal and stationary frequencies of the initial vowel /ɛ/ in the 30 Russian VCV words studied. Entries have been rounded off to the nearest 25 cps.

	i/i	-	-a	-o	-u	row averages
b′-	-275	-250	-350	-225	-375	-300
b-	-350	-325	-425	-400	-450	-400
d′-	75	75	75	50	0	75
d-	-200	-250	-250	-250	-200	-225
g′-	275	250	250	250	300	275
g-	100	200	0	-200	-375	

575 cps and 1750 cps, respectively.

As can be seen from Table XIV-1 the formant transitions leading from the initial vowel to the stop are different in the palatalized and unpalatalized cases. Thus, the F_2 transition of the initial vowel of, for example, /ɛd′a/ is rising and that of /ɛda/ falling (see Fig. XIV-2). This seems to imply that the palatalization of the stop consonant starts already at the offset of the initial vowel.

In the utterances beginning with /ɛb′-/, /ɛb-/, /ɛd′-/, /ɛd-/, and /ɛg′-/ the F_2 transition contained in the initial vowel seems to be practically independent of the identity of the final vowel. This is seen by reading across rows of Table XIV-1. This independence, which is in marked contrast with the Swedish and American English data, is no doubt due to the phonemic fixation of the vowel substrate of the stops in Russian.

In the case of /ɛg-/, however, the influence appears to be very great. Thus, in /ɛgɛ/, shown in Fig. XIV-4, the F_2 transition of the initial vowel rises by approximately 200 cps, whereas it falls by approximately 375 cps in /ɛgu/. This seems to contradict the assumption of a fixed vowel substrate. It would be wrong to conclude, however, that the vocalic component of Russian /g/ is an automatic, phonemically irrelevant feature, for x-ray pictures of Russian /k′/ - /k/ and /g′/ - /g/[4, 5] show that the shape of the tongue at the moment of closure of an unpalatalized /g/ approaches that of the vowel /ɨ/.

The most likely explanation of the data of Table XIV-1 is that the /g/ is indeed associated with a concomitant ɨ-like substrate but that a slight coarticulation with the final vowel causes a change in the place of closure without substantially affecting the shape of the tongue. As is well known, a small displacement of the place of constriction in the palatovelar region may cause a big change in the F-pattern of the acoustic output, probably big enough to account for the last row of Table XIV-1. This question should be definitely settled on the basis of x-ray motion pictures.

The explanation just proposed conforms with the idea that the thing controlled by

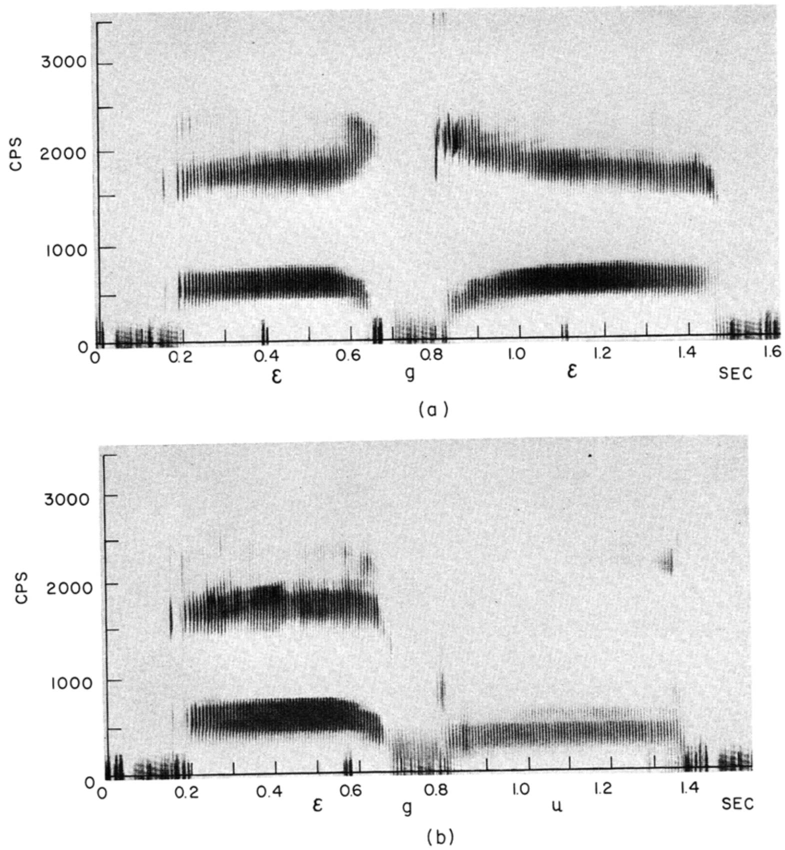

Fig. XIV-4. Sound spectrograms of the utterances /εgε/ and /εgu/. The second formant transitions of the initial vowels are different because of coarticulation with the final vowels.

the talker is not the shape of the vocal tract but rather the intrinsic state of the articulatory organs themselves, especially that of the tongue.

Finally, even though the vowel substrate of the Russian stops is used for phonemic differentiation, the case of /g/ in Table XIV-1 shows that this circumstance does not entirely eliminate the automatic type of coarticulation observable in American English and Swedish.

S. E. G. Öhman

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