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Fricative–stop coarticulation: Acoustic and perceptual evidence

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Eight native speakers of American English each produced ten tokens of all possible CV, FCV, and VFCV utterances with V = [ɑ] or [u], F = [s] or [ʃ], and C = [t] or [k]. Acoustic analysis showed that the formant transition onsets following the stop consonant release were systematically influenced by the preceding fricative, although there were large individual differences. In particular, $F3$ and $F4$ tended to be higher following [s] than following [ʃ]. The coarticulatory effects were equally large in FCV (e.g., /stɑ/) and VFCV (e.g., /ɑsdɑ/) utterances; that is, they were not reduced when a syllable boundary intervened between fricative and stop. In a parallel perceptual study, the CV portions of these utterances (with release bursts removed to provoke errors) were presented to listeners for identification of the stop consonant. The pattern of place-of-articulation confusions, too, revealed coarticulatory effects due to the excised fricative context.

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INTRODUCTION

In two previous papers (Mann and Repp, 1981; Repp and Mann, 1981) we described an effect of a preceding fricative on stop consonant perception: When a synthetic syllable ambiguous between [tɑ] and [kɑ] was preceded by a fricative noise appropriate for [s] (plus a brief silence appropriate for stop closure), listeners reported [skɑ] more often than [stɑ]. A preceding [ʃ] noise, on the other hand, had little effect on the perceived place of stop articulation. In a series of experiments, we eliminated several possible explanations of the contrasting effects of [s] and [ʃ], such as a simple response bias, auditory contrast, or cues in natural frication to stop place of articulation. We concluded that the perceptual context effect most likely reflects listeners' expectation of a coarticulatory interaction between a stop consonant and a preceding fricative—namely, a shift in place of stop consonant articulation towards that of the fricative.

In our second paper (Repp and Mann, 1981), we reported data that supported this hypothesis. Starting with fricative–stop–vowel utterances obtained from a single speaker, we examined listeners' stop consonant perception after the fricative noise and the stop release burst had been removed. The stops in these truncated CV syllables were more often perceived as having a relatively forward place of articulation when the excised fricative had been [s] than when it had been [ʃ]. In addition, acoustic measurements of the same stimuli showed that the onset frequency of the second formant ($F2$) following the stop release was lowered by about 100 Hz in the context of [s], relative to [ʃ] context. A possible difference in $F3$ onset in the opposite direction was also indicated. Thus $F2$ and $F3$ onsets were more widely separated in [s] context than in [ʃ] context—a pattern that is consistent with the hypothesized forward shift in place of stop articulation following [s], considering the well-known fact that $F2$ and $F3$ onsets are more widely separated in [tɑ] than in [kɑ].

While these data suggested that fricative–stop coarticulation can occur, their generality was uncertain. After all, the data derived from only three tokens of a few utterances produced by a single speaker. In the present paper, we report acoustic measurements and supplementary perceptual tests using utterances collected from eight new speakers.

I. ACOUSTIC MEASUREMENTS

A. Method

1. Speakers

Four males (AA, LL, RM, VG) and four females (VM, SP, PP, FBB), all native speakers of American English, were enlisted. They included two senior phoneticians (AA, LL), an experienced speech scientist (FBB), a graduate student in phonetics (PP), and four speakers with little formal training.

2. Utterances

The experimental utterances included all possible combinations of an initial vowel ([ɑ], [u], or absent), a fricative ([s], [ʃ], or absent), a stop ([t] or [k]), and a final vowel ([ɑ] or [u]), with the restriction that two vowels in an utterance be the same. Table I lists the individual utterances, both in phonetic notation and in the spelling in which they were read by the subjects. Note that the stop consonants, although unaspirated in both FCV and VFCV contexts, were phonologically voiceless in FCV utterances where they were part of a syllable-initial fricative–stop cluster, but phonologically voiced in VFCV utterances where they were in syllable-initial position.[1] Thus this set of utterances enabled us to assess not only the effect of a preceding fricative on stop articulation but also the sensitivity of that effect to the presence of an intervening syllable boundary.

Ten randomized lists of these utterances were typed on a sheet of paper. The lists included four other utterances ([sɑ], [ʃɑ], [su], and [ʃu]) whose analysis we

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TABLE I. The set of utterances used.

[tɑ]	da	[tu]	du
[kɑ]	ga	[ku]	gu
[stɑ]	sta	[stu]	stu
[skɑ]	ska	[sku]	sku
[ʃtɑ]	shta	[ʃtu]	shtu
[ʃkɑ]	shka	[ʃku]	shku
[ɑstɑ]	asda	[ustu]	usdu
[ɑskɑ]	asga	[usku]	usgu
[ɑʃtɑ]	ashda	[uʃtu]	ushdu
[ɑʃkɑ]	ashga	[uʃku]	ushgu

will not report here. The CV syllables ([tɑ], [kɑ], [tu], [ku]) were added after speakers VM and SP had been recorded; thus CV data were available for six speakers only.

3. Recording procedure

The utterances were produced in a soundproof booth in front of a Shure dynamic microphone and recorded on a Crown 800 tape recorder. Speakers were given sample pronunciations by the experimenter and were instructed to read at an even pace and as naturally as possible. Speakers varied in their assignment of stress in the disyllabic (VFCV) utterances: three (AA, LL, VM) stressed the second syllable while the other five stressed the first syllable. This unintended variation in stress offered the opportunity to observe any possible effects of this variable.

4. Measurement procedure

Individual utterances were input from audio tape to a Federal Scientific UA-6A spectrum analyzer. The results of the spectral analysis were stored in the memory buffer of a GT-40 computer and displayed on a Hewlett–Packard oscilloscope. By using a cursor below a spectrogram of the whole utterance, individual time frames could be selected whose smoothed average spectrum was displayed above the spectrogram, while the corresponding portion of the digitized waveform appeared on a second screen. Thus the selection of frames for spectral analysis was guided by both waveform and spectrographic information. Spectral cross sections were computed over a 25.6-ms time frame; the step size from one frame to the next was 12.8 ms. The spectrum was displayed as a point plot with a resolution of 40 Hz. Spectral peaks corresponding to formants were determined from this display by eye and noted down by hand. Appropriate adjustments were made for asymmetric shapes of spectral peaks; occasional multiple peaks, apparently due to a formant straddling two or more individual harmonics, were averaged. In doubtful cases, the spectra of the preceding and following time frames were taken as a guideline.

Because of the laborious nature of this manual procedure, the measurements had to be restricted to the most crucial aspects of the stimuli—the onset frequencies of $F2$ and $F3$ (and in some cases, $F4$) following the stop release. Since the release burst of the stop usually showed a highly irregular spectrum (especially for alveolar stops), it was ignored, and measurements were taken from the first frame that showed a clear formant pattern, normally including $F1$ (signifying the onset of voicing). Additional measurements were taken from the next two frames (only from the next frame in the case of speaker AA whose utterances were the first measured), so that formant transitions were tracked over approximately 50 ms.

Note that this procedure provides a conservative estimate of coarticulatory effects due to the fricative, since any such effects are likely to be most pronounced at the point of stop release and to decrease with distance from the release. Although coarticulatory changes in the release burst may exist (cf. Repp and Mann, 1981, for indirect evidence) they cannot be assessed easily by the present method. Thus the present investigation was concerned solely with coarticulatory changes in the formant transitions following the release burst.

The raw data consisted of $F2$ and $F3$ (and, sometimes, $F4$) for three (two in the case of AA) consecutive frames of each of ten tokens of 20 utterances (16 in the case of VM and SP) produced by eight speakers. Missing data due to omissions, mispronunciations, or gross acoustic anomalies were rare. A more common source of missing data was the weakness of some formants in certain utterances, particularly $F3$ in utterances containing [ku]. For some speakers, as noted below, no reliable data for $F3$ could be obtained in these instances.

B. Results and discussion

The measurements of $F2$ and $F3$ in FCV and VFCV utterances were subjected to separate five-way analyses of variance, with the factors syllable boundary (FCV versus VFCV), fricative ([s] versus [ʃ]), vowel ([ɑ] versus [u]), stop ([t] versus [k]), and time (three frames). Speaker AA was not included in these analyses because of missing data.

Figure 1 gives an impression of the general frequency characteristics of the formant transitions, regardless of preceding context. The transitions are depicted as trajectories in the $F2$–$F3$ plane, separately for each speaker's productions of [tɑ], [kɑ], [tu], and [ku], averaged over the five contexts [-], [s-], [ʃ-], [ɑs-] (or [us-]), and [ɑʃ-] (or [uʃ-]). Except for the few cases with missing data points, each trajectory is based on three points in time separated by 12.8 ms, with 50 measurements per point. In the left panel, it can be seen that all speakers had falling $F2$ transitions in both [tɑ] and [kɑ], but two different patterns emerged for $F3$: For five speakers (LL, RM, VG, SP, PP), the $F3$ transitions were falling for [tɑ] and slightly falling for [ka]; for the remaining three speakers (AA, VM, FBB), $F3$ was completely flat for [tɑ] but rising for [kɑ]. These individual differences may indicate that the second group of speakers produced [ɑ] with a relatively high $F3$. In the right panel, we see that all speakers (except for VM in [ku]) showed falling $F3$ transitions in [tu] but a flat $F3$ in [ku]. Note that after about 50 ms of formant movement, the formants of [tɑ] and [kɑ], and of [tu] and [ku], were still widely separated, suggesting rather long formant transitions and/or variations in vowel quality dependent on the preceding stop (particularly in [u]).

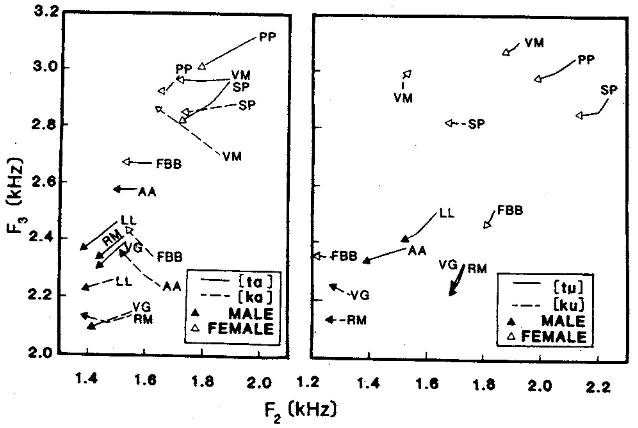

FIG. 1. Formant transition patterns for individual speakers' productions of [tɑ], [kɑ], [tu], and [ku], averaged over five different contexts and depicted as trajectories in the F2–F3 plane. Data for [ku] are missing from speakers AA, LL, and PP, due to unreliable F3 measurements.

The trends shown in Fig. 1 are all highly significant, and they are generally in agreement with other data in the literature. We will not dwell on them here, as our primary concern was the effect of preceding fricative context. We examined this effect in terms of the difference in formant onset frequencies following [s] and [ʃ].

Table II shows these differences (in Hz) for $F2$, broken down by individual utterance pairs and speakers but averaged over the three time frames. A positive difference indicates that $F2$ was higher following [s] than following [ʃ]. Italics indicate differences that were significant at the $p < 0.01$ level in individual t tests. It can be seen that, on the average, $F2$ was 4 Hz lower following [s] than following [ʃ]—a nonsignificant difference. Nevertheless, out of 64 individual comparisons, 20 were significant—a proportion far exceeding chance. Of these 20 differences, 8 were positive and 12 negative, which confirms the absence of any general trend. Since there was no pattern in the data, these significant coarticulatory effects must be considered entirely idiosyncratic.

In the analysis of variance, however, there was a significant triple interaction between fricative, stop, and time, $F(2,12) = 14.0, p > 0.001$: the $F2$ transitions of alveolar stops started an average of 40 Hz lower in [s] context than in [ʃ] context, and this difference diminished over time. The $F2$ transition of velar stops, on the other hand, was essentially unaffected by fricative context. No other effect involving the fricative factor was significant, except for one marginally significant four-way interaction with no clear associated pattern.

The $F3$ measurements are shown in Table III. The picture was quite different here. On the average, $F3$ was 46 Hz higher following [s] than following [ʃ], $F(1,6) = 51.8, p < 0.001$. Of the 61 individual comparisons, 28 were significant, and every single one of them was positive. Thus, even though there was considerable variability across speakers and tokens, the evidence for coarticulatory variation in $F3$ is very strong. The correlation between the entries in Tables II and III is −0.07, indicating no relation between context-induced shifts in $F2$ and $F3$.

The coarticulatory effect on $F3$ did not decrease over time, suggesting that fricative context may have influenced not only the articulation of the following stop but also that of the following vowel. Two interactions involving the fricative factor reached significance in the analysis of variance. One [between fricative, syllable boundary, and time, $F(2,12) = 4.2, p < 0.05$] revealed that the coarticulatory effect *increased* over time in FCV utterances but did not change at all over time in VFCV utterances. According to the second interaction [between fricative, vowel, stop, and time, $F(2,12) = 8.0, p < 0.01$] the coarticulatory effect increased over time in [u] context and for alveolar stops in [ɑ] context, but decreased over time for velar stops in [ɑ] context. The reasons for these complex patterns are not clear.

Table IV shows the $F4$ measurements, which were obtained for only five speakers and yielded reliable data for only about half the comparisons (mostly those involving stops preceding [u]).[2] Nevertheless, the pattern was very clear: out of 19 individual comparisons, 18 were positive, and 13 of these were significant. Thus there was a clear tendency for $F4$ to be higher following [s] than following [ʃ]. This tendency seemed to be even stronger than that for $F3$, the average difference in Table IV being more than twice as large (102

TABLE II. Coarticulation effects on $F2$: $[F2]_s - [F2]_ʃ$ in Hz. Italics indicate difference is significant ($p < 0.01$) by t test.

Utterances	Speakers								
	AA	LL	RM	VG	VM	SP	PP	FBB	Mean
[stɑ] – [ʃtɑ]	10	−11	*−37*	*−65*	32	−24	−21	*63*	−7
[skɑ] – [ʃkɑ]	36	−13	1	*85*	52	8	0	17	23
[stu] – [ʃtu]	*98*	5	*−64*	*73*	*−76*	−12	−47	−44	−8
[sku] – [ʃku]	4	−20	*76*	7	49	*−164*	−44	*−147*	−30
[ɑstɑ] – [ɑʃtɑ]	4	*−35*	*−63*	*−57*	−13	15	−3	−4	−20
[ɑskɑ] – [ɑʃkɑ]	*131*	*51*	3	−3	*137*	44	−33	40	46
[ustu] – [uʃtu]	−22	9	*−81*	*−83*	−15	4	21	*−71*	−30
[usku] – [uʃku]	−10	9	−8	−15	−31	−1	33	−44	−8
Mean	31	−1	−22	−7	17	−16	−12	−24	−4

TABLE III. Coarticulation effects on $F3$: $[F3]_s - [F3]_ʃ$ in Hz. Italics indicate difference is significant ($p < 0.01$) by t test. Differences in parentheses are based on a small number of tokens only.

Utterances	Speakers								
	AA	LL	RM	VG	VM	SP	PP	FBB	Mean
[stɑ] – [ʃtɑ]	−20	*101*	(54)	*43*	43	37	27	*117*	50
[skɑ] – [ʃkɑ]	*86*	1	*76*	*61*	−21	*64*	29	*49*	43
[stu] – [ʃtu]	*74*	*89*	*123*	*67*	28	*83*	*75*	−9	66
[sku] – [ʃku]		(82)	12	(19)	0	*71*	112	11	(44)
[ɑstɑ] – [ɑʃtɑ]	*54*	33	−24	*97*	12	28	−1	*145*	43
[ɑskɑ] – [ɑʃkɑ]	(60)	8	*104*	40	−55	11	*79*	*45*	37
[ustu] – [uʃtu]	*108*	*61*	15	*64*	*88*	24	*125*	1	61
[usku] – [uʃku]			*25*	(9)	−29	25	(46)	*55*	(22)
Mean	60	54	48	50	8	43	62	52	46

Hz) than that in Table III. However, the changes in $F3$ and in $F4$ were not significantly correlated ($r = 0.21$).

A comparison of the $F3$ data from each fricative context with the measurements for CV utterances did not confirm our expectation (based on the earlier perceptual data) that the coarticulatory effect would be primarily due to [s]. On the contrary, the data suggest that it was almost entirely due to [ʃ]. However, this difference was in large measure due to a single subject (PP), and because this analysis could be done on five speakers' utterances only, the effects did not reach statistical significance.

We recognize that it is difficult to infer articulatory processes from acoustic data. Given our hypothesis that the place of stop articulation shifts towards that of the preceding fricative (Repp and Mann, 1981), one might expect that the formant transitions of a stop following [s] would be more [t]-like (indicating a forward shift) than those of a stop following [ʃ], which would be more [k]-like (indicating a backward shift). Since [t] has a somewhat higher $F3$ onset than [k] in both vocalic contexts (cf. Fig. 1), our finding of a higher $F3$ onset following [s] is consistent with these expectations. What is not consistent is (1) the absence of any coarticulatory shifts in $F2$, particularly in [-u] context where [t] and [k] are characterized by widely differing frequencies (cf. Fig. 1), and (2) the finding of higher $F4$ onsets following [s], for our data indicate that $F4$ is considerably higher in [ku] than in [tu], with less difference between [kɑ] and [tɑ]. In view of these ambiguities, we turned to a perceptual test in the hope that it might shed some light on the direction of the shifts in stop place articulation.

TABLE IV. Coarticulation effects on $F4$: $[F4]_s - [F4]_ʃ$ in Hz. Italics indicate difference is significant ($p < 0.01$) by t test.

Utterances	Speakers				
	RM	VM	SP	PP	FBB
[stu] – [ʃtu]	35	*187*	*145*		47
[sku] – [ʃku]		16	*123*		
[ɑstɑ] – [ɑʃtɑ]	−1			*185*	
[ɑskɑ] – [ɑʃkɑ]	*79*			27	
[ustu] – [uʃtu]	*100*	36	*83*	*260*	*84*
[usku] – [uʃku]	*105*	*89*	*148*	*199*	

II. PERCEPTUAL DATA

To complement our acoustic measurements, we gathered perceptual data for a subset of the utterances described above, supposing that labeling responses to FCV and VFCV utterances from which the fricative noise and release burst had been removed might provide another means of assessing any coarticulation between fricative and stop—a procedure used successfully by Repp and Mann (1981). We began by focusing only on those utterances which contained the vowel [ɑ], but later extended our experiment to utterances containing [u].

A. Method

1. Subjects

The subjects were ten students from Bryn Mawr and Haverford Colleges, all native speakers of English, of whom eight were paid volunteers and two were participating as part of a class project.

2. Stimuli

To create the truncated CV syllables, the utterances were digitized at 10 kHz using the Haskins Laboratories PCM system. Individual utterances were displayed on a storage oscilloscope, and the beginning of the first clear pitch pulse following the stop release burst was located in the waveform. Only the stimulus portion following that point was retained. The burst duration (from burst onset to the cutoff point) was recorded. This was done for five tokens of each of all eight speakers' utterances containing the vowel [ɑ] and for four speakers' (AA, LL, PP, FBB) utterances containing the vowel [u].[3]

The truncated CV syllables were assembled into sequences and recorded onto audio tape. A separate tape was created for each speaker and for each vowel, each tape containing five repetitions of each of the 40 stimuli (five tokens of each of eight utterances) in separately randomized blocks. Interstimulus interval was 2.5 s, with 7.5 s between blocks.

3. Procedure

All subjects participated in two different sessions of approximately one hour. The [ɑ] tapes for speakers LL, VM, RM, and SP were played in the first session and those for speakers AA, PP, VG, and FBB were played in the second session, in the order as listed. Six of the subjects returned for a third session in which all of the [u] tapes were played. The stimuli were presented in a quiet room over TDH-39 earphones. Subjects were required to label each stimulus as containing an initial "b," "th" (as in *that*), "d," "g," or, if necessary, "-" (no consonant).

B. Results and discussion

The data obtained with speaker SP's [ɑ] utterances were excluded from analysis because listeners found it difficult to hear any stops and responded fairly randomly. The combined confusion matrix for the remaining seven speakers' [ɑ] utterances is shown in the left half of Table V. Comparing utterances differing only in the nature of the original fricative, it is evident that "d" (and "th") responses were somewhat more frequent when the fricative context had been [s], and that "g" (and "b") responses were more frequent when the fricative context had been [ʃ]. Except for the trend in the "b" responses, this pattern is consistent with our hypothesis that [s] leads to a forward shift in the place of articulation of a following stop.

Responses of "d" and "g" were subjected to separate four-way analyses of variance with the factors speaker, stop ([t] versus [k]), fricative ([s] versus [ʃ]), and syllable boundary (FCV versus VFCV). We discovered that, while the effect of fricative context on "d" responses did not reach significance, that on "g" responses did, $F(1,9)=14.5, p<0.01$. However, the extent of this difference varied across speakers, $F(6.54)=8.3, p<0.001$. It was also greater for alveolar stops than for velar ones, $F(1,9)=8.1, p<0.05$, and greater for FCV utterances than for VFCV utterances, $F(1.9)=13.8, p<0.01$. Several other statistical interactions were significant, indicating high variability among utterances produced by different speakers, but consistency in subjects' perception.

To see whether the speaker variability in the perceptual data was related to the similar variability observed in the acoustic measurements, we subtracted the percentage of "g" responses (which had shown a significant effect of fricative context) for each utterance which had contained [s] from that for the corresponding utterance which had contained [ʃ], and then correlated these difference scores (four values for each of seven speakers) with the $F3$ difference measures of Table III. The correlation was positive and significant, $r(28)=0.44, p<0.02$. Thus pairs of utterances showing a relatively large acoustic effect of fricative context (i.e., higher values of $F3$ following [s]) also tended to elicit a larger difference in "g" responses (viz., fewer "g" responses to utterances that originally included [s]).

The confusion matrix for the [u] utterances is shown in the right-half of Table V. There we see that alveolar stops were most often identified as "d," but truncated velar stops received predominantly "b" responses—a finding that may be explained by the similarity of the (equally minimal) formant transitions of labial and velar stops in [u] context (cf. Kewley-Port, 1981), together with a possible listener bias to respond "b" in this context. The table reveals little systematic variation contingent on the excised fricative context, except for a trade between "b" and "g" responses to velar stops: when the preceding fricative had been [s], "b" responses were less frequent, and "g" responses more frequent, than when it had been [ʃ]. These differences, as reflected in the stop by fricative interaction, were significant in separate analyses of "b" responses, $F(1,5)=18.4, p<0.01$, and of "g" responses, $F(1,5)=15.0, p<0.01$. However, there were a number of significant interactions with other factors, especially with speakers, reflecting again high between-speaker variability coupled with relatively low between-listener variability. There was no significant correlation with the acoustic measurements for [u] utterances.

III. CONCLUSIONS

The results of our present studies, even though they are based on a very large amount of data, are not quite as clear as we had hoped. Nevertheless, two conclusions seem appropriate. First, we have obtained rather solid acoustic evidence for a coarticulatory shift in stop production contingent on preceding fricative context. This shift was reflected in generally higher onset values of $F3$ and $F4$ following [s] than following [ʃ]. Second, we have found additional evidence for fricative-induced shifts in stop production in listeners' perception of the vocalic formant transitions, although the correlation between the acoustic and perceptual findings was

TABLE V. Confusion matrices for truncated syllables.

	Percent responses									
	V=[ɑ]					V=[u]				
Utterance	"b"	"th"	"d"	"g"	"-"	"b"	"th"	"d"	"g"	"-"
[(s)tV]	16	13	55	10	6	6	5	80	8	1
[(ʃ)tV]	16	9	52	17	6	3	6	80	9	2
[(s)kV]	24	8	21	41	6	63	4	3	19	11
[(ʃ)kV]	26	6	14	46	8	70	3	2	14	11
[(Vs)tV]	6	13	64	9	8	7	3	84	5	1
[(Vʃ)tV]	9	10	63	12	6	3	3	87	6	1
[(Vs)kV]	10	10	32	42	6	52	5	5	29	9
[(Vʃ)kV]	14	8	30	41	7	62	3	4	23	8

weak. Variability of coarticulatory effects across speakers and tokens was unexpectedly large. Unfortunately, neither the acoustic nor the perceptual data have a straightforward articulatory interpretation, which leaves open the question of whether the place of stop articulation indeed shifts toward that of a preceding fricative, or whether some more complex articulatory adjustment is involved. Presumably, only direct observations of speech production will shed light on this issue. In this study and our previous ones, we have laid the foundation for this further research by establishing fricative–stop coarticulation as a real phenomenon in the acoustic and perceptual domains.

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[1]They were also phonologically voiced in CV utterances, where unaspirated [t] and [k] may have alternated with prevoiced [d] and [g]. To simplify the notation, we refer to all stops as [t] or [k].

[2]Average $F4$ onset frequencies for five individual speakers (based on a subset of the utterances) were 2862 Hz (RM), 3733 Hz (VM), 3962 Hz (SP), 4303 Hz (PP), and 3626 Hz (FBB).

[3]To check for any possible differences in burst duration contingent on preceding fricative, an analysis of variance was conducted on the burst duration measurements. For the [ɑ] utterances, there was no significant effect of the preceding fricative. Bursts were, however, significantly longer for velar stops (24 ms) than for alveolar ones (16 ms), $F(1,7) = 39.2$, $p < 0.001$. Bursts were also significantly longer following a syllable boundary, $F(1,7) = 11.3$, $p < 0.02$, although the difference was only 2 ms. In the [u] utterances, too, bursts were longer for velar stops (24 ms) than for alveolar ones (20 ms), $F(1,3) = 28.5$, $p < 0.05$, and bursts tended to be longer following [s] (24 ms) than following [ʃ] (20 ms), $F(1,3) = 10.7$, $p < 0.05$, both effects being due to unusually short bursts for alveolar stops following [s] (17 ms). The syllable boundary effect was reversed here but nonsignificant.

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