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FIBERSCOPIC STUDY ON LARYNGEAL ADJUSTMENTS FOR SYLLABLE-FINAL APPLOSIVES IN KOREAN*

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1. Introduction

It is known that Korean stop consonants in syllable-initial position are of three types: lax, aspirated and forced (or unaspirated). In syllable-final position, however, these three different types are merged to a single type with the same place of articulation, although the original three-way distinction is preserved in the Korean orthographic (Hangul) system. Thus the syllable-final stops are phonetically realized as voiceless "applosives" which are characterized by the absence of oral release. Similar changes also take place for the three-way distinction of the affricates as well as the two-way distinction of the fricatives in syllable-initial position, all of these sounds being manifested as the dental voiceless applosive in syllable-final position. The sound systems of these consonants is summarized in Tab. 1.

Table 1. List of Korean stops, affricates and fricatives.

	syllable-initial			syllable-final
	lax	forced	aspirated	applosive
stop	p- [p,b] t- [t,d] k- [k,g]	pp- [p'] tt- [t'] kk- [k']	p^h- [p^h] t^h- [t^h] k^h- [k^h]	-p, -p^h [p^l] -t, -t^h, -c, -c^h, -s, -ss [t^l] -k, -k^h, -kk [k^l]
affricate	c- [tʃ, dʒ]	cc- [tʃ']	c^h- [$tʃ^h$]	
fricative	s- [s, ʃ]	ss- [s']		
nasal	m- [m] , n- [n]			-m [m] , -n [n] , -ŋ [ŋ]
lateral	r- [ɾ]			-r [l]
glottal	h- [h]			-h [ ] (zero)

Phonetic characteristics of the three-way or two-way distinction of these syllable-initial sounds have been reported by acoustic and physiological observations (Umeda and Umeda, 1965; Kim, 1970; Hirose et al. 1974; Kagaya, 1974). The aim of the present study is to investigate the laryngeal adjustments for these syllable-final stops in various phonological conditions. Our preliminary results on the velar stop sound which were reported previously (Sawashima and Park, 1979) can be summarized as follows:

1) The basic laryngeal feature of the Korean syllable-final stop is characterized by a small degree of glottal opening which begins almost synchronously with oral closure.

2) In the case of the final stop followed by the syllable-initial stop of the same place of articulation, the laryngeal feature of the final stop appears to be assimilated to the following stop, as far as the glottal opening is concerned.

3) The basic laryngeal feature for the three-way distinction of the syllable-initial stops appears to apply to the final stop, when the stop recovers its original characteristic, as indicated in the Korean orthography, by the following vowel under certain linguistic conditions.

The present paper reports on further results obtained from additional subjects and speech materials with three places of articulation of the syllable-final applosives, [p^{l}], [t^{l}] and [k^{l}].

2. Experimental Procedures

2-1 Test materials

Meaningful words containing syllable-final applosives [p^{l}], [t^{l}] and [k^{l}] were prepared according to the different phonological environments described below, where the test words are presented in both orthography and phonetic transcription.

i: Syllable-final applosives at the end of sentence.

Test words were:

"cip"	[tʃip^{l}]	(house)
"ciph"	[tʃip^{l}]	(straw)
"nac"	[nat^{l}]	(daytime)
"nach"	[nat^{l}]	(face)
"ses"	[set^{l}]	(three)
"nas"	[nat^{l}]	(sickle)
"kyəth"	[k^{h}jɔt^{l}]	(side)
"kɛk"	[kɛk^{l}]	(quest)
"puəkh"	[puək^{l}]	(kitchen)
"pakk"	[pak^{l}]	(outside)

The test words were pronounced in a sentence "ike _____" (This is _____).

ii: Syllable-final applosives followed by the syllable-initial velar stops.

In this case, the following lax stop is pronounced as the forced stop. The test words were:

"ip kwa k^{h}o"	[ip^{l} k'wak^{h}o]	(mouth and nose)
"os kaci"	[ot^{l} k'adʒi]	(a kind of cloth)
"kyəthkaci"	[kjɔt^{l} k'adʒi]	(side branch)
"pɛk kaci"	[pɛk^{l} k'adʒi]	(a hundred kinds)

"cip kkaci"	[tʃipˡ k'adʒi]	(to the house)
"cipʰ kkaci"	[tʃipˡ k'adʒi]	(to the straw)
"os kkaci"	[otˡ k'adʒi]	(to the cloth)
"ses kkaci"	[setˡ k'adʒi]	(up to three)
"nas kkaci"	[natˡ k'adʒi]	(to the sickle)
"hɔs kkum"	[hɔtˡ k'um]	(unpractical hope)
"nac kkaci"	[natˡ k'adʒi]	(until the daytime)
"nacʰ kkaci"	[natˡ k'adʒi]	(to the face)
"kyətʰ kkaci"	[kjɔtˡ k'adʒi]	(to the side)
"cip kʰi"	[tʃipˡ kʰi]	(house key)
"os kʰeisw"	[otˡ kʰeisɯ]	(suitcase)
"tɛk kʰi"	[tɛkˡ kʰi]	(your key)
"puəkʰ kʰi"	[puəkˡ kʰi]	(key to the kitchen)

In this series, test words with the forced and aspirated syllable-initial velar stops were also prepared as references:

"pɛ kkaci"	[pɛk'adʒi]	(to the boat)
"ce kʰi"	[tʃe kʰi]	(my key)

The test words were embedded in a frame sentence "ike _____ ta" (This is _____).

iii: Syllable-final applosives followed by the syllable-initial fricatives.

In this case, the following lax fricative is pronounced as the forced fricative. Also, the syllable-final [tˡ] is replaced by the following fricative sound. The test words were:

"cip se"	[tʃipˡ s'e]	(rent)
"tɛs sɛ"	[tɛtˡ s'ɛ]	(the fifth day)
"hɛss so"	[hɛtˡ s'o]	(it was done.!!)
"mit so"	[mitˡ s'o]	(do believe)
"s ɛk si"	[s ɛkˡ s'i]	(bride)
"ip ssirwm"	[ipˡ s'irɯm]	(quarrel)
"ius ssaum"	[iutˡ s'aum]	(fight of neighboring persons)
"kot sswlta"	[kotˡ s'ɯlda]	(sweep immediately)
"hoŋ p ɛk ssaum"	[hoŋpɛkˡ s'aum]	(competition of red team vs. white)

In this series, test words with the lax and forced syllable-initial fricatives were also prepared as references:

"si"	[si]	(time)
"ssirwm"	[s'irɯm]	(Korean-style wrestling)

The test words were embedded in a frame sentence "ike _____ (i) ta" (This is _____).

2-2 Subjects

Three female Korean adults, M., P. 1 and P. 2, and two male Korean adults, L and C, served as subjects. They were all native speakers of the Seoul dialect, and also fluent speakers of Japanese. The subjects pronounced the test sentences which were transcribed in Korean orthography (Hangul), the speaking rate and intensity being kept as constant as possible within the natural ranges of the subjects.

2-3 Data collection

A flexible fiberscope was inserted through the nose of the subject and the laryngeal view was filmed at a rate of 50 frames per second simultaneously with the speech recording. The instrumentation has been reported elsewhere (Sawashima, 1977). A magnified image of the laryngeal films was examined, frame by frame, for each pertinent consonant segment. The distance between the tips of the vocal processes of the arytenoid cartilages was measured when the glottis was open. For each subject, the number of utterance samples obtained for each of the test items was three to four.

3. Results and Comments

3-1 Syllable-final applosives at the end of the sentence

Fig. 1 shows the time courses of the glottal width for typical utterance samples of the three subjects. In each graph the abscissa is the time axis demarcated by the interval of each film frame (20 msec), and the ordinate corresponds to the apparent glottal width measured on an arbitrary scale. The downward arrow indicates the time point of the articulatory closure. For all subjects, the glottis begins to open at, or one or two frames after, the oral closure for all the test words, the extent of the opening remaining small for a time period of 4 to 5 frames after closure.

The results confirm those of our preliminary report and there is no difference in the contour of the glottal time curve either for the different types indicated by the orthography or the different places of articulation.

3-2 Syllable-final applosives followed by the syllable-initial velar stops

Here we first compare the glottal time curves for the sequences of the syllable-final approsives followed by the lax and forced velar stops. Typical examples for the five subjects are presented in Fig. 2a-c. In the figure, the vertical line and the upward arrow indicate the time point of the oral release and the voice onset of the following vowel, respectively. The glottal time curve for the syllable-initial "kk-" of "p kkaci" is presented as the reference for each subject. In all subjects except C, there is a small degree of glottal opening during the oral closure for the syllable-initial forced stop, the glottis being completely closed or nearly closed at the oral release. These findings are consistent with previous reports (Kagaya, 1974; Sawashima and Park, 1979) and are characteristic in laryngeal adjustments for the forced stop. In Subj. C, there is no measurable separation of the arytenoid cartilages, the membraneous portion of the glottis being covered by the

epiglottis.

The degree of glottal opening for the consonant sequences of the syllable-final applosives followed by the lax and forced stops is almost the same as that of the syllable-initial forced stop. The glottis at the oral release for these consonant sequences is also completely closed or nearly closed as in the syllable-initial forced stop. These results confirm those of our previous report irrespective of the difference in the place of articulation. There appears to be a tendency that the duration of the closure for "-pk-" and "-sk-" sequences is longer than that for "-kk-".

Typical examples of the glottal time curves for the consonant sequences of the final applosives followed by the aspirated velar stop are displayed in Fig. 3a-c. For each subject the glottal time curve for the syllable-initial "k^h-" of "ce k^hi" is presented as the reference. In some utterances there is the devoicing of the vowel "i" that follows the "k^h-". The downward arrows on the glottal time curves in those cases indicate the oral closure of the following "t" of the frame "–ta." For the initial "k^h-", there is a wide opening of the glottis, the peak glottal width being reached slightly before the oral release. This finding is also consistent with previous reports (Kagaya, 1974; Sawashima and Park, 1979) and is characteristic of the laryngeal adjustments for the aspirated stop. In the consonant sequences also, the glottis begins to open at or slightly after the oral closure, the peak glottal width being as large as that of the initial aspirated stop. The time curves for the consonant sequences are nearly identical irrespective of the difference in the place of articulation of the syllable-final applosives which precede the aspirated velar stop. Also, the glottal time curves for the consonant sequences appear to be basically identical to that of the syllable-initial aspirated stop. There is a longer duration of the oral closure and consequently a more gradual slope in the opening process of the glottis for the consonant sequences as compared to the syllable-initial aspirated stop. Some of the consonant sequences show the oral release after the peak glottal width is reached. These results are consistent with our previous report which revealed a strong influence of the following aspirated stop to the glottal condition of the preceding syllable-final applosive.

3-3 Syllable-final applosives followed by the syllable-initial fricatives.

In this series, samples were obtained from three subjects. Typical examples of the glottal time curves for the syllable-final applosives followed by the lax and forced fricatives are displayed in Fig. 4.a, b. For each subject, the glottal time curves for the syllable-initial "s-" of "si" and "ss-" of "ssirwm" are also presented as the reference. There is a fairly large glottal opening both for the lax and forced fricatives. The degree of glottal opening tends to be larger for the lax sound as compared to the forced one, although for Subj. P. 2 there is the devoicing of the following vowel "i" in "si".

It is known that the lax fricative is pronounced as the forced sound when it follows the syllable-final applosives. Glottal time curves show little change with difference in the type of the following fricative sound. The time curves also show little change with difference in the place of articulation of the syllable-final applosives. It is noted that for this particular series there is no articulatory stop closure for "-s" and "-t" which are

otherwise manifested as [t^{h}]. The result is a continuation of the fricative sound. The glottal time curves for sequences of the syllable-final applosives followed by the fricatives appear to be similar to that of the syllable-initial forced fricative rather than the lax type. A greater degree of glottal opening for "-ks-" than for "-kss-" in Subj. M and a longer duration of the glottal separation for "-ks-" than for "-kss-" in Subj. P. 2 may be accounted for by the devoicing of the following "i" and "t" of "seksita."

Acoustic study has revealed that the most noticable difference between the lax and forced fricatives is observed at the transition from the fricative noise to the following vowel (Umeda and Umeda, 1965). Our samples also need to be examined on this respect.

The results obtained here are summarized as follows:

1. The basic laryngeal feature of the Korean syllable-final applosives is characterized by a small degree of glottal opening, which begins at or slightly after the oral closure.

2. In the case of the final applosives followed by the initial stops and fricatives, the laryngeal feature of the final applosives appears to be assimilated by that of the following consonant irrespective of the difference in the place of articulation, as far as the glottal abduction/adduction is concerned.

References

1) Hirose, H., C. Y. Lee and T. Ushijima (1974): "Laryngeal Control in Korean Stop Production." J. Phonetics 2, 145-152.
2) Kagaya, R. (1974): "A Fiberscopic and Acoustic Study of the Korean Stops, Affricates and Fricatives, "J. Phonetics 2, 161-180.
3) Kim, C-W. (1970): "A Theory of Aspiration," Phonetica 21, 107-116.
4) Sawashima, M. (1977): "Fiberoptic Observation of the Larynx and other Speech Organs" in Dynamic Aspects of Speech Production.
5) Sawashima, M. and H. S. Park (1979): "Laryngeal Adjustments for Syllable-final Stops in Korean: Some Preliminary Results of Fiberoptic Observation" Ann. Bull. RILP, No. 13, 83-89.
6) Umeda, H. and N. Umeda (1965): "Acoustical Features of Korean 'Forced' Consonants". Gengo Kenkyu, 48, 23-33.

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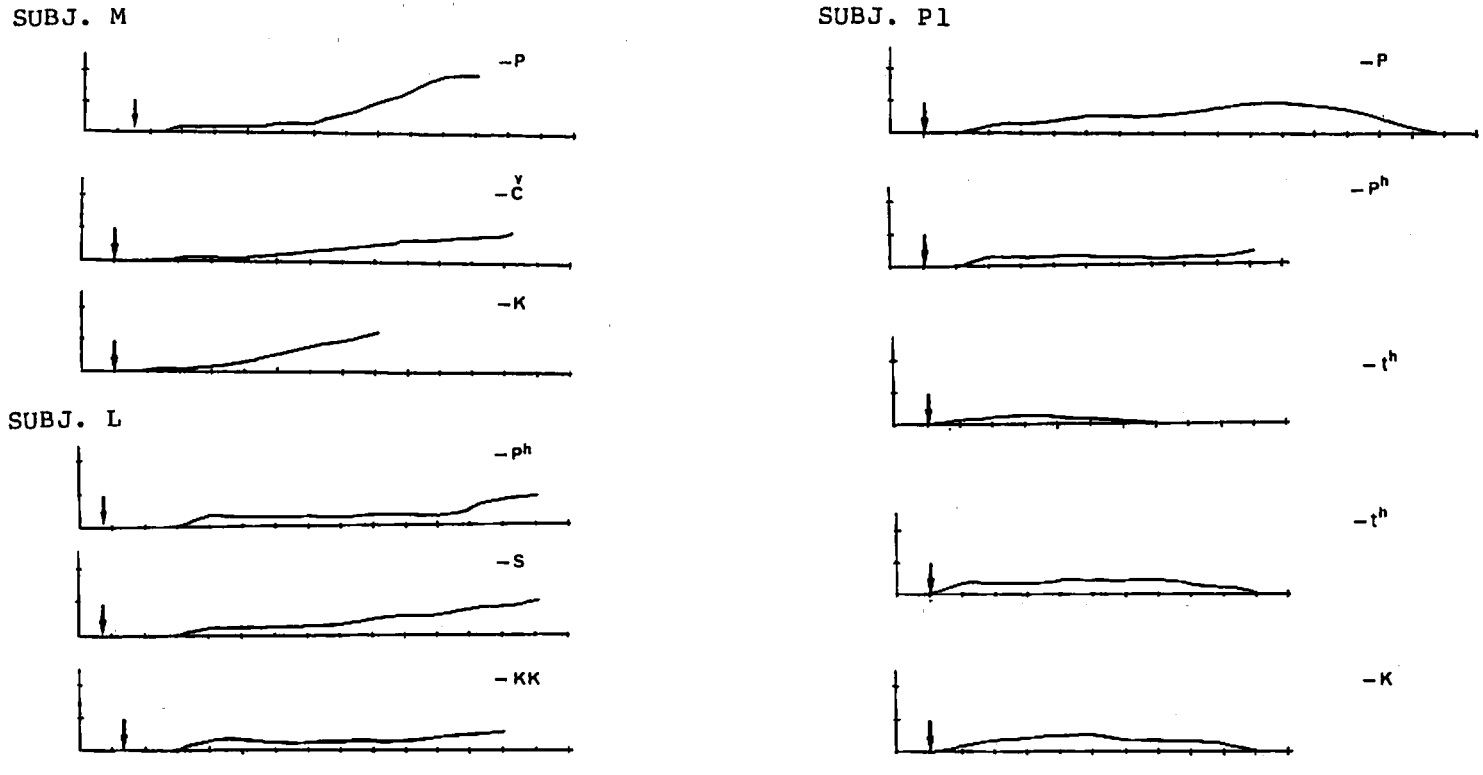

Fig. 1 Typical examples of the glottal time curves for the syllable-final applosives at the end of sentence.

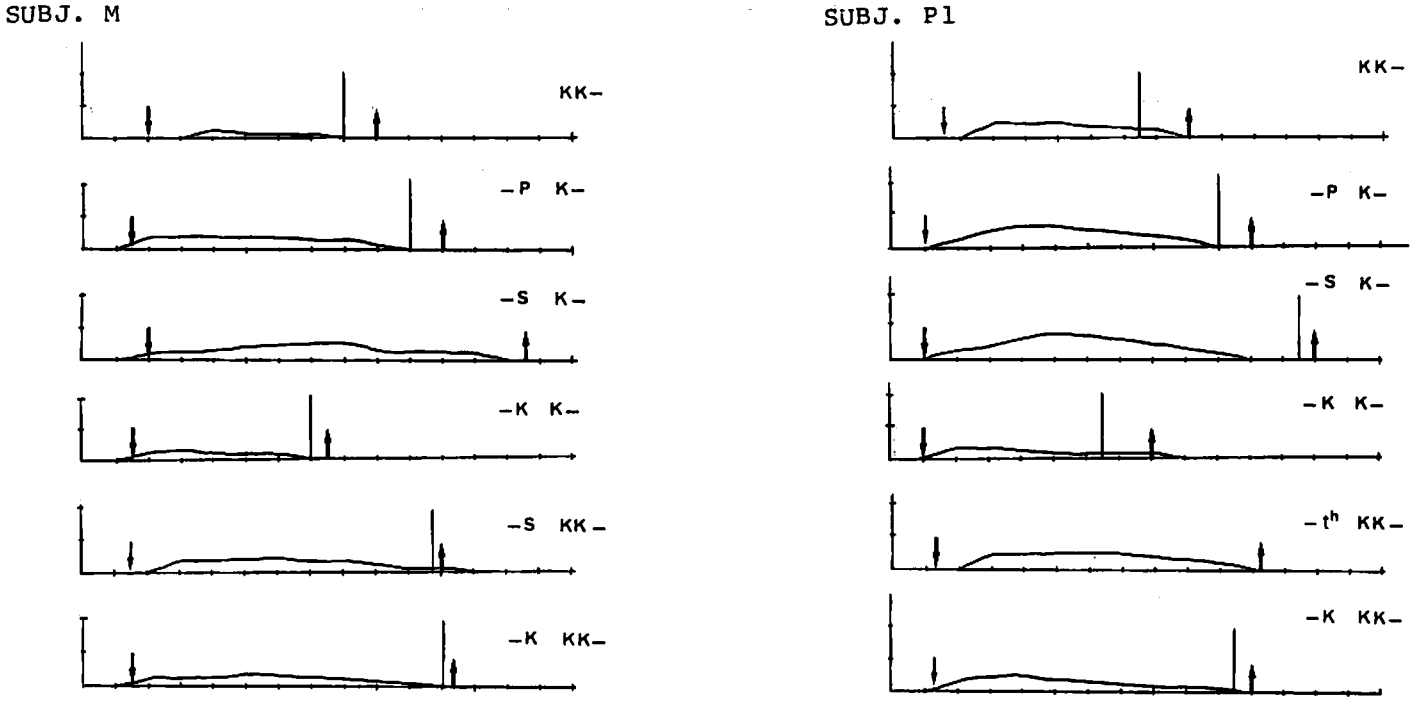

Fig. 2a Typical examples of the glottal time curves for the sequences of the syllable-final applosives followed by the lax and forced velar stops. (Subj. M and P1)

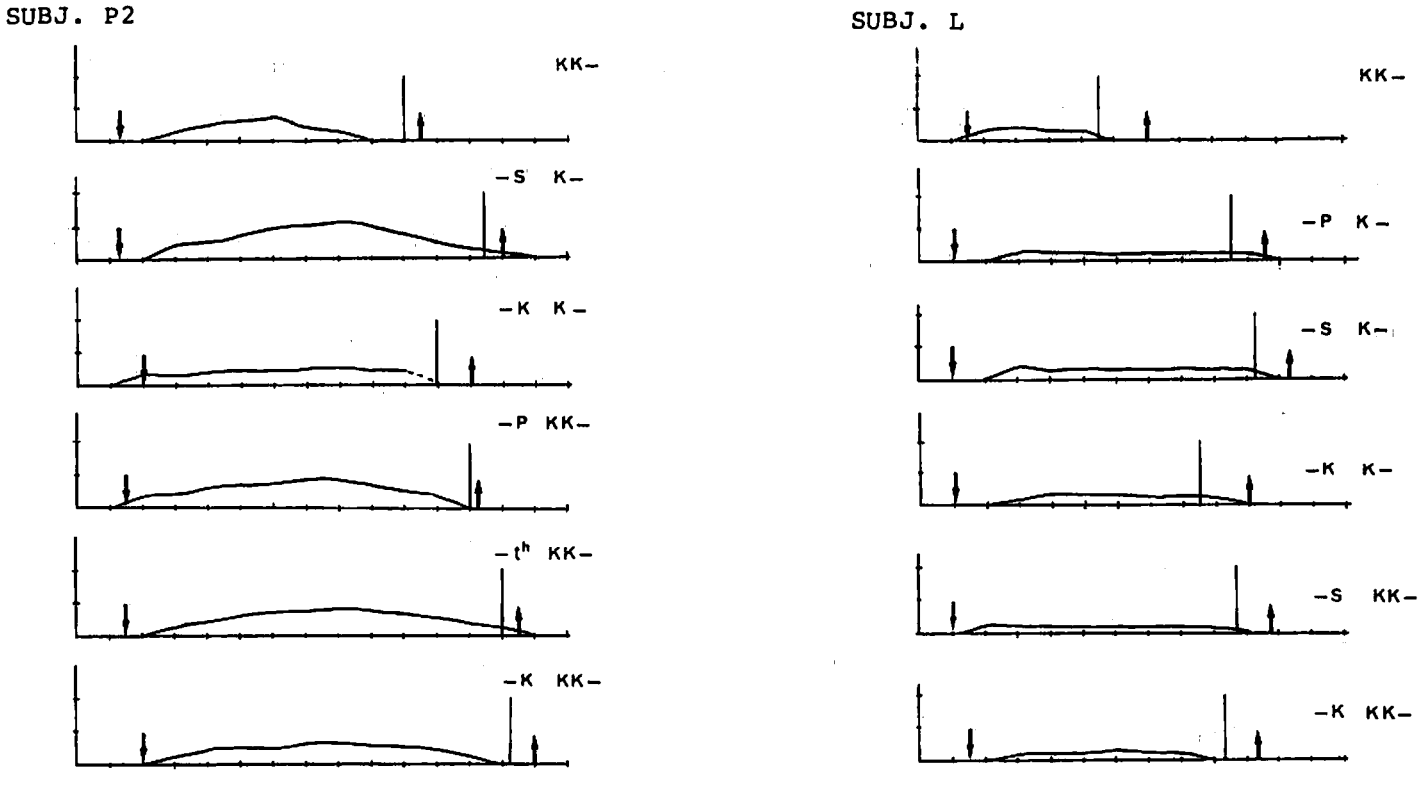

Fig. 2b Same display as Fig. 2a for Subj. P2 and L.

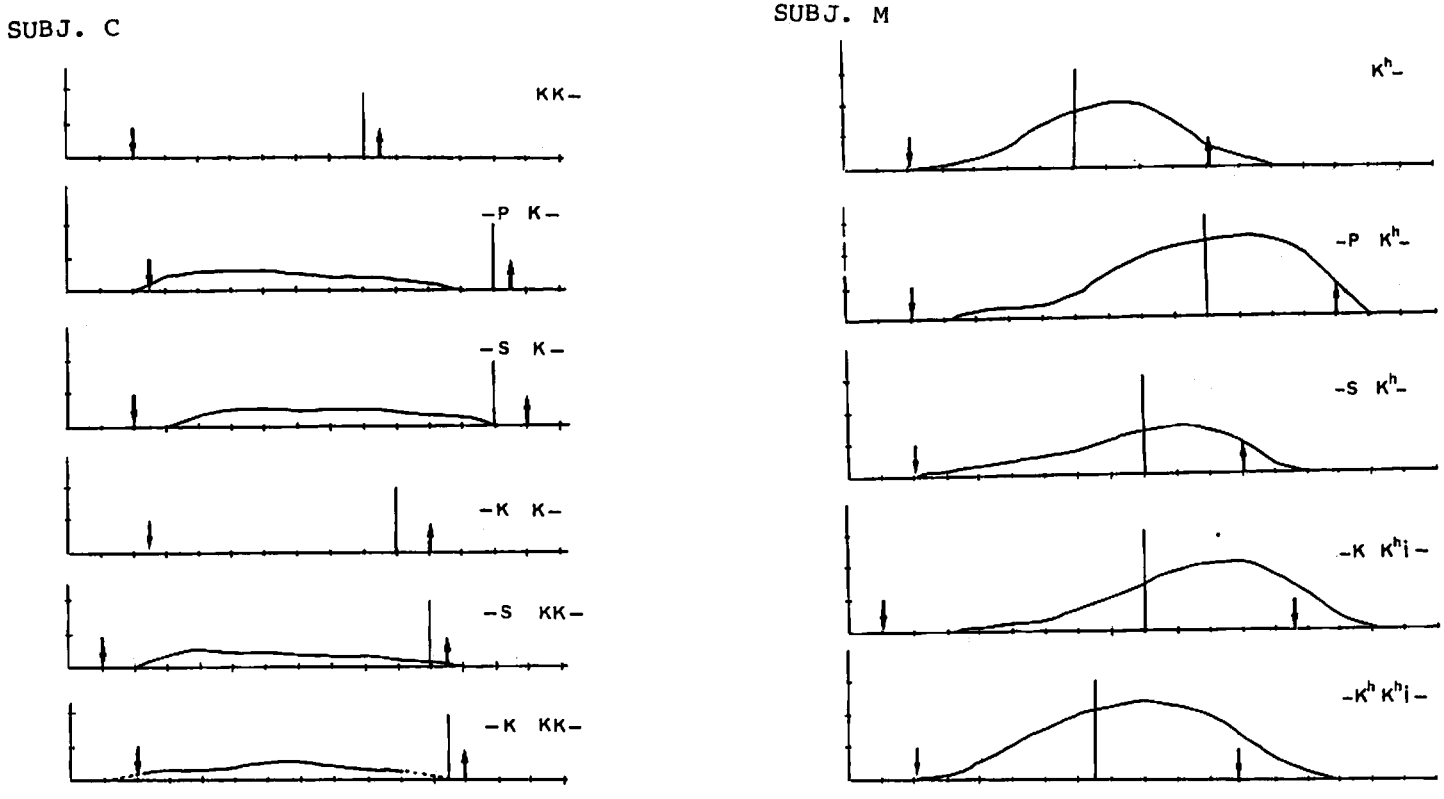

Fig. 2c Same display as Fig. 2a for Subj. C.

Fig. 3a Same display as Fig. 2 for the syllable-final applosives followed by the aspirated velar stop. (Subj. M)

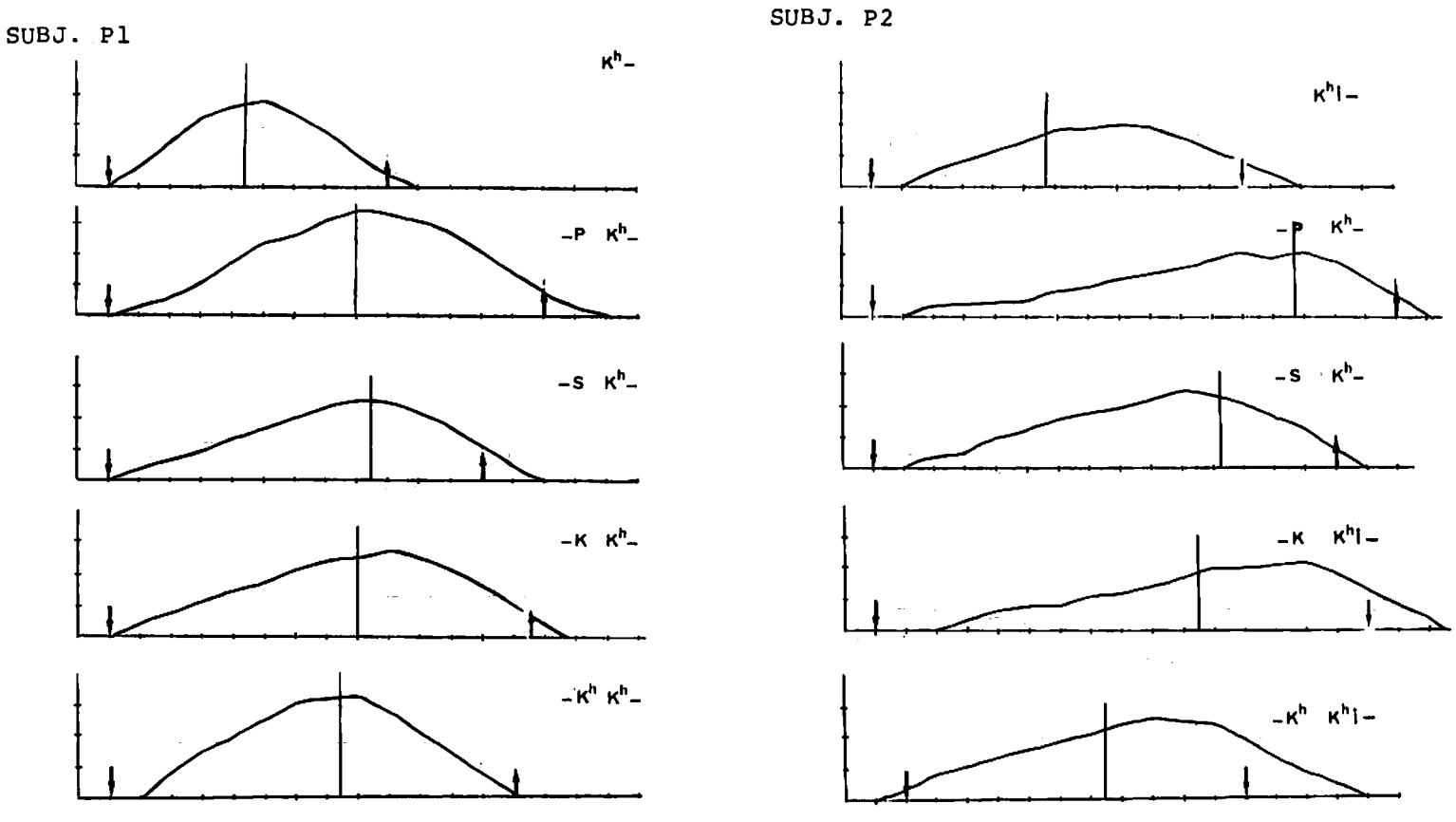

Fig. 3b Same display as Fig. 3a for Subj. P1 and P2.

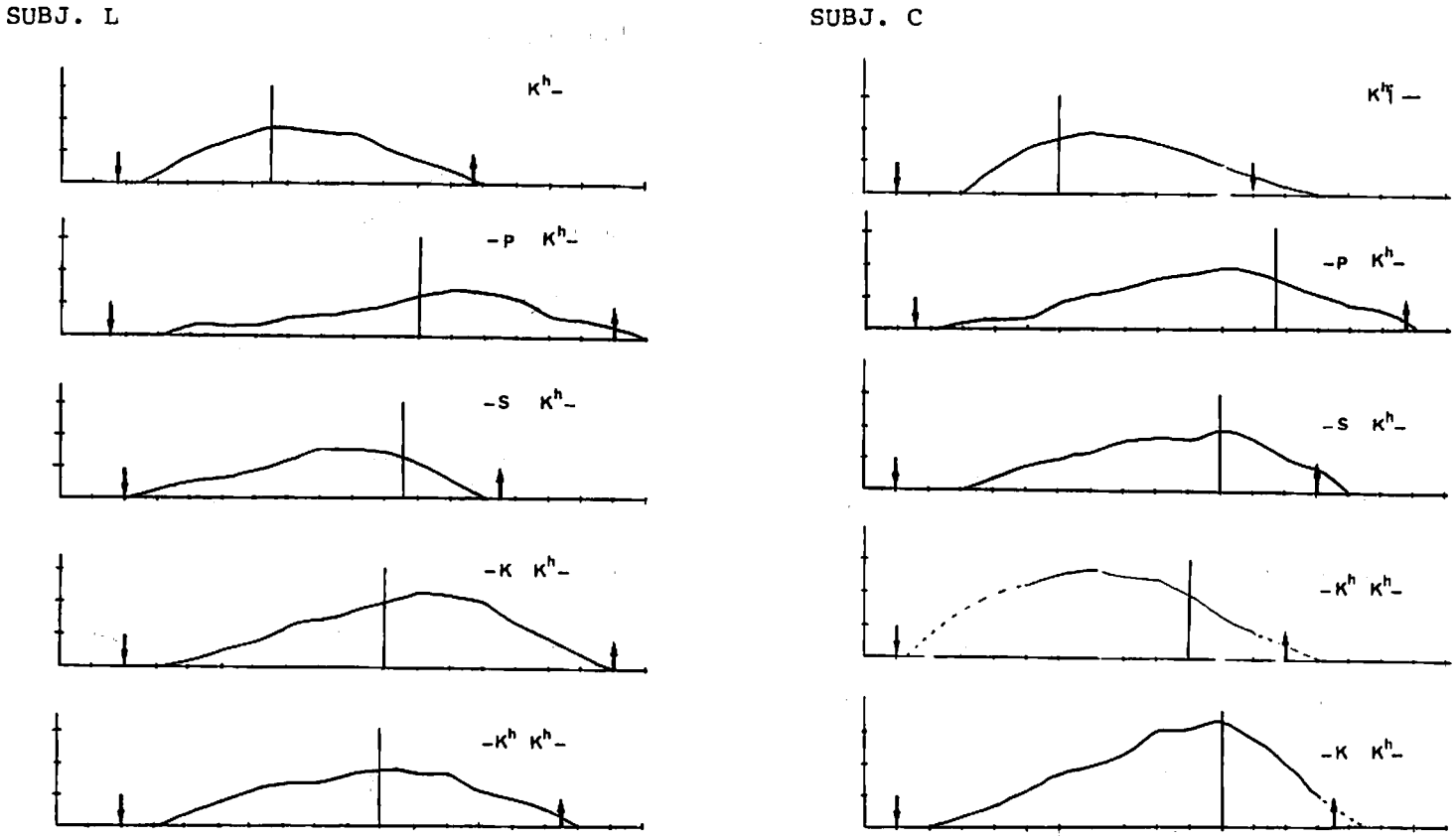

Fig. 3c Same display as Fig. 3a for Subj. L and C.

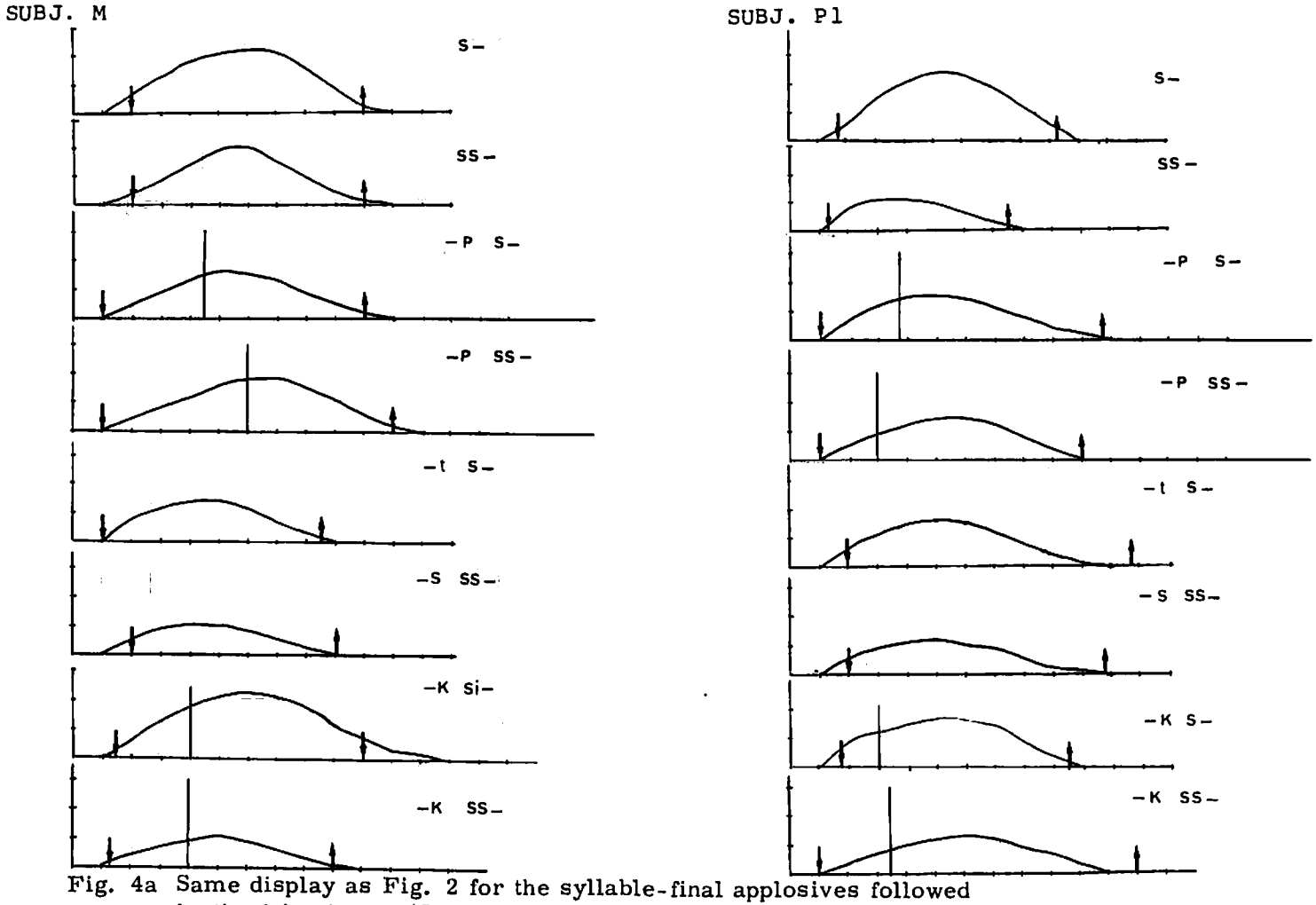

Fig. 4a Same display as Fig. 2 for the syllable-final applosives followed by the fricatives. (Subj. M and P1)

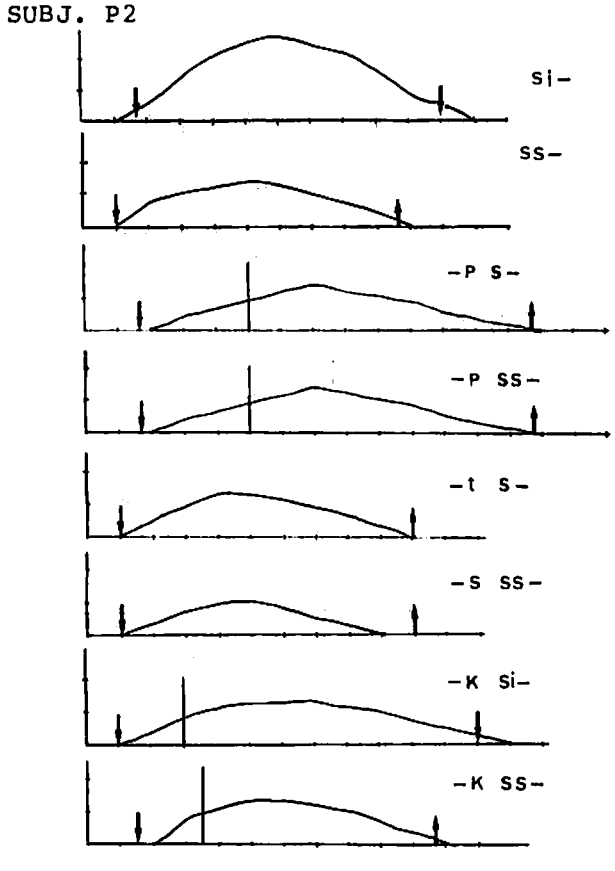

Fig. 4b Same display as Fig. 4a for Subj. P2.