Speech Communication 2 (1983) 145–147
North-Holland

ON IDENTIFYING SYLLABLE BOUNDARIES

Fredericka BELL-BERTI and Lawrence J. RAPHAEL

St. John's University, Jamaica, NY 11439; Herbert H. Lehman College of the City University of New York, Bronx, NY 10468; Haskins Laboratories, 270 Crown Street, New Haven, CT 06510 USA

Received 18 March 1983

Introduction

Although phoneticians do not agree on the definition of the syllable, they do agree that all languages permit consonant-vowel syllable units embodying maximally contrastive constricted-vs.-open articulations. However, even descriptions of syllables as units composed of one or more consonants plus a vowel presume definitions of consonants and vowels that are themselves often grounded in their distributional properties (Andresen, 1968), including their roles in the syllable. Thus, one is struck with the potential value of definitions of the consonant, vowel, and syllable in terms outside of their linguistic functions.

The need for such definition has been recognized for some time, and has led to some physiological research on the nature of the syllable, including that of Stetson (1951) and Ladefoged (1967). The conflicting results of these two efforts to identify the basis of the syllable in the respiratory musculature have, in turn, led to examination of the articulatory musculature for evidence of syllables and syllable-boundaries. Thus, Kozhevnikov and Chistovich (1965) hypothesized that all of the consonants and vowels of a syllable are co-produced. Support for this suggestion has been offered by Gay (1978), who found that articulatory movement to the second vowel (of a VCV string) begins at, but not before, the beginning of the intervocalic consonant.

Additional support for this marking of syllable boundaries in coarticulatory terms may be found in the 'trough phenomenon' (cf. Bell-Berti and Harris, 1974). In one example, for a sequence such as [ipi], the tongue musculature responsible for raising and advancing the tongue for the two [i] vowels relaxes in association with the production of [p], although conventional descriptions of [p] articulation do not specify a tongue position for this consonant. Similar results for vowel-related lip-rounding activity have been reported by Gay (1975). In short, there appear to be two distinct 'vowel' gestures, presumably one for each syllable.

If, in fact, these 'troughs' are related to syllable boundary events, we would expect them to be evident in VCV sequences, and, furthermore, to find evidence of them in the resulting formant patterns, since the interposition of a consonant between vowels has long been known to affect systematically the formant frequencies of those vowels (cf. Lindblom, 1963; Öhman, 1966). The nature of these effects appears to depend on the extent to which the vowels and consonants share the tongue and lips as articulators, and, presumably also on the consonant-vs.-vowel difference between these segments. The results of some recent studies of speech production suggest that neither [h] nor [ʔ] interrupts V-to-V articulations in the way that other consonants do (Harris and Bell-Berti, 1982).

Traditional articulatory descriptions suggest two alternatives concerning the status of [h] and of [ʔ] as consonants. On the one hand, since they are classified as consonants, we would expect them to produce coarticulatory effects of the same sort as other fricatives and stops. On the other hand, since they are described as non-lingual non-labial in their articulation, we would expect them to result in small, and similar, coarticulatory effects.

Table 1
Second formant frequencies at midpoint (see text) of second vowel of VCV sequences

	consonant		V_1 = [i]	V_1 = [a]	V_1 = [u]
A	b	V_2 = [i]	1983	2042	2075
	h		2083	2058	2125
	ʔ		2153	2185	2175
B	b	V_2 = [a]	1258	1275	1254
	h		1183	1238	1179
	ʔ		1233	1247	1230
C	b	V_2 = [u]	868	888	908
	h		805	808	875
	ʔ		803	845	788

Methods

The study reported here was undertaken to examine the coarticulatory effects of [h] and [ʔ] on vowel second-formant frequency. This study employed spectrographic analysis of [pVhVp], [pVʔVp], and [pVbVp] sequences; the vowels were [i, a, u]; all 27 combinations of vowels and consonants were used. The VCV sequences were spoken within a longer utterance frame; primary stress was always placed on the second vowel of the VCV sequence. The subject, a native speaker of New York City English, spoke each utterance 10 times.

Wide-band spectrograms were made of the tokens of each utterance. Measurements of second-formant frequency were made at the onset, vowel midpoint (for [a]) or *F*2 minimum (for [u]) or peak (for [i]), and end of both vowels for all utterances. The average second-formant frequency was then calculated for each measurement point for each utterance.

Results

A summary of the second-formant frequencies for the second, stressed, vowel, is offered in Table 1. We see that utterances containing [b] have less extreme formant values than do utterances containing [h] or [ʔ]. Furthermore, in five of the six comparisons involving movement toward extreme front and back vowels (Table 1, A and C), the formant values suggest that tongue position is more extreme for utterances containing [ʔ] than [h].

Both of these results support the findings of Harris and Bell-Berti (1982), who reported that a 'trough' between vowels in articulatory data is substantially less likely for [ʔ] and [h] than for a labial consonant, although [h] is occasionally accompanied by a trough.

Our results revealed minimal coarticulation between [h] and [ʔ] with surrounding vowels. Since consonants are often portrayed as units that delimit syllables, and evidence of their coarticulation with vowels strengthens that portrayal, these results raise questions about the functional homogeneity within the group of segments traditionally classified as consonants.

Acknowledgements

This work was supported by NINCDS Grant NS-13617 and BRS Grant RR-05596 to the Haskins Laboratories.

References

B.S. Andresen, *Pre-glottalization in English standard production*, Norwegian University Press, Oslo, Norway, 1968.

F. Bell-Berti and K.S. Harris, "More on the motor organization of speech gestures", *Haskins Laboratories Status Report on Speech Research*, 1974, SR-37/38, pp. 73–77.

O. Engstrand, "Acoustic constraints of invariant input representation? An experimental study of selected articulatory movements and targets", *RUUL 7* (Reports from Uppsala University Department of Linguistics), 1981, pp. 67–94.

T. Gay, "Effect of speaking rate on diphthong formant movements", *J. Acoust. Soc. Am.,* Vol. 44, 1968, pp. 1570–1573.

T. Gay, "Some electromyographic measures of coarticulation in VCV utterances", *Haskins Laboratories Status Report on Speech Research,* 1975, SR-44, pp. 137–146.

K.S. Harris and F. Bell-Berti, On consonants and syllable boundaries, *Haskins Laboratories Status Report on Speech Research,* 1982, SR-70, pp. 293–299.

V.A. Kozhevnikov and L.A. Chistovich, *Rech, Artikulyatsiya, i vospriyatiye,* translated *Speech: Articulation and perception,* Joint Publications Research Service, Washington, DC 1966, Vol. 30, p. 543. (Originally published, 1965.)

P. Ladefoged, *Three Areas of Experimental Phonetics,* Oxford University Press, London, 1967.

B. Lindblom, "Spectrographic study of vowel reduction", *J. Acoust. Soc. Am.,* Vol. 35, 1963, pp. 1773–1781.

S.E.G. Öhman, "Coarticulation in VCV utterances: Spectrographic measurements", *J. Acoust. Soc. Am.,* Vol. 39, 1966, pp. 151–168.

R.H. Stetson, *Motor Phonetics: A study of speech movements in action,* North-Holland. Amsterdam, 1951.