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On Consonants and Syllable Boundaries

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Arthur Bronstein, in his book *The Pronounciation of American English* (1960), follows the convention of dividing the sounds of the language into two classes—the consonants and the vowels. Within this rubric, he assigns the glottal stop [?], and the glottal fricative [h] to the consonant class, as other textbook authors do. To choose a few examples, [?] is described as a "glottal plosive" and [h] as a "breathed glottal fricative" by Daniel Jones (1956); [?] as a "laryngeal stop" and [h] as a "laryngeal open consonant" by Heffner (1949). The authors thus make the tacit assumption that these sounds share some property with the stops and fricatives and contrast, in some manner, with vowels. In part, this view is a consequence of their distributional properties (Andresen, 1968) and, indeed, their role in the syllable. However, this decision leaves us with the further problem of deciding what syllables are, within which the consonants and vowels

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may have roles. To continue with our sampling of phonetics texts, we find Malmberg (1963) and MacKay (1978) observing that, although phoneticians may differ on the definition of a syllable, the untrained speaker of a language usually has a clear idea of the number of syllables in an utterance, and this intuitive reality suggests that there must be some corresponding articulatory reality. For convenience, we will ignore the problems of the more general definitions of the syllable (Bell & Hooper, 1978; Pulgram, 1970), though we note that the problem of finding articulatory meaning for the syllable is made more acute by the failure of efforts to find easy distributional definitions.

Modern physiological research on the syllable begins with the work of R. H. Stetson (1951), who suggested that the syllable was physiologically defined by an initiating and a terminating burst of activity from the muscles of the chest wall, the internal and external intercostal muscles, resulting in a distinct chest pulse for each syllable. This attractive concept was effectively torpedoed by the classic experimental work of Ladefoged and his colleagues (Ladefoged, 1967), who were able to show that there were not discrete bursts of muscle activity corresponding to individual syllables and, indeed, that the manner of interaction of muscular and nonmuscular forces in the expiratory cycle made the idea of a syllable based on separate muscular syllable pulses theoretically implausible. More recently, attempts have been made to salvage the concept of an articulatory syllable by assuming that its boundaries may be discovered by careful examination of the activity of the upper articulators, rather than the respiratory muscles.

Many current theories stem from the work of Kozhevnikov and Chistovich (1965), originators of the concept of the articulatory syllable, defined by coarticulation. In brief, they suggested that all elements in a single syllable are coproduced. As a consequence, for example, if a syllable contains a rounded vowel, the consonants associated with the syllable would be likely to take on "rounding" attributes. As a correlate, one might suppose that in sequences of an unrounded-vowel syllable, followed by a rounded-vowel syllable, an examination of rounding characteristics of the intervocalic consonants might permit the specification of a syllable boundary. In fact, Kozhevnikov and Chistovich suggest an "articulatory" syllable consisting of a vowel and its preceding consonant string. This basic suggestion has been amplified by Gay, who finds that in a VCV string, the articulatory movement toward a second vowel begins at, but never earlier than, the onset of the first intervocalic consonant (Gay, 1978); in other words, the syllable boundary is marked in coarticulatory terms.

Support has been provided for this idea by the so-called "trough phenomenon" (Bell-Berti & Harris, 1974; Gay, 1975). Briefly, it has been shown that if two rounded vowels of the same phonetic specification are produced in sequence, with a single consonant or string of consonants unspecified for rounding between the vowels, as in [utu], the lip muscles will relax between the two vowels, so that the consonants are produced with only partly rounded lips. The same phenomenon can be demonstrated, as well, in sequences like [ipi], where the tongue, which must be raised and fronted for the two identical front vowels, relaxes in association with production of the [p], although the conventional or feature description of [p] does not specify a tongue position for the consonant. In both cases, there are two "vowel" gestures, one, apparently, for each syllable. However, for reasons of economy of production, one might expect a "held" gesture for the second of the two vowels, since the production of the intervening consonantal gesture does not appear to be in conflict with the vowel.

While these facts can be used to argue against some models of coarticulation (Bell-Berti & Harris, 1981), they provide support for coarticulatory marking of syllable boundaries if a trough, indicating a consonant gesture, is formed at all syllable boundaries. In the textbook descriptions of phonetic sequences we provided earlier, we understood that a syllable boundary must occur somewhere in the sequence VCV. The trough phenomenon provides evidence of boundary marking because a vowel-to-vowel gesture, which might, apparently, be produced continuously, is not. If [h] and [ʔ] are consonants, they should interrupt a vowel-to-vowel sequence in the same way as [t] production interrupts vowel rounding.

The general hypothesis is that the "trough" phenomenon is a general syllable boundary marker. We wanted to examine [h] and [ʔ] for the two syllable sequences where the original observations of the trough phenomenon were made. We ask, Do [h] and [ʔ] cause relaxation of the tongue for [i] sequences, and Do [h] and [ʔ] cause relaxation of lip protrusion for [u] or [ɔ] sequences?

At present, the most effective way of observing the movements of the tongue is in lateral view cineradiography. We have made extensive observations of tongue movements using a special-purpose setup, the x-ray microbeam installation at the University of Tokyo (see Kiritani, Itoh, & Fujimura, 1975).[1] For the purposes of the present discussion, we merely noted that the output of the system is a series of plots of the x and y coordinates of the position of pellets affixed to the articulators. The speaker was a male native of New York State, with no pronounced speech defects.

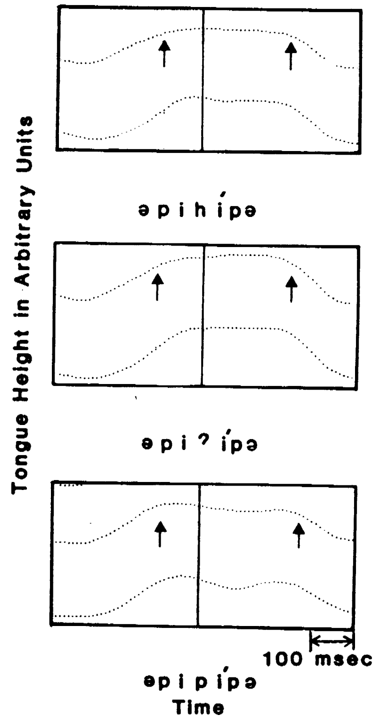

FIGURE 1. X-ray microbeam traces for the syllables [əpipípə], [əpihípə] and [əpiʔípə]. The plots show the vertical coordinate of a pellet on the tongue blade and mid-tongue position. Coordinate values with larger *y* values show greater tongue height. The long vertical line on each trace shows the time of the end of voicing for the first [i]. The two upward-pointing arrows show the beginning and end of the two-vowel sequence.

Figure 1 shows the position of the *y* coordinate for two pellets as a function of time for three nonsense syllable sequences, [əpihípə], [əpiʔípə] and [əpipípə]. An examination of these three tokens, and others like them that vary in stress and speaking rate, leads to the general impression that a trough is substantially less likely for [ʔ] and [h] than [p]; some samples of [h] show a trough, but most do not. Of course, more quantitative observations are necessary.

It is somewhat easier to observe the movement of the lips in the production of rounded vowels. Although it is possible to use x-ray methods, an easier technique is to observe the forward protrusion of the lips in rounded vowel production either directly by monitoring movies of the lips in profile, or indirectly by recording the output of a suitably placed strain gauge.

Figure 2 shows the lip movement for the sequences [lɔʔɔl] and [lɔtɔl]. Unfortunately, we did not examine the sequence [lɔhɔl]. The speaker was a female native of the Washington, D.C., area, with normal articulation. The recording shows the output of a strain gauge placed on the lower lip in such a way that forward movement of the lip causes bending of the plate (Abbs & Gilbert, 1973).[2] An examination of the figure suggests that there is a trough in the lip-protrusion curve for [t], but not for [ʔ].

Unfortunately, as with many experimental facts, the results just described may be interpreted in several ways which are not mutually exclusive. One possibility is that there is no coarticulatory definition of the syllable boundary. A second possibility is that the "laryngeal" stops [h] and [ʔ] do not form a class with [t] and [p] so that [h] and [ʔ] are not "true" consonants and thus cannot lead to boundaries even if [VhV] and [VʔV] are judged to be disyllabic. A third possibility is that existence of

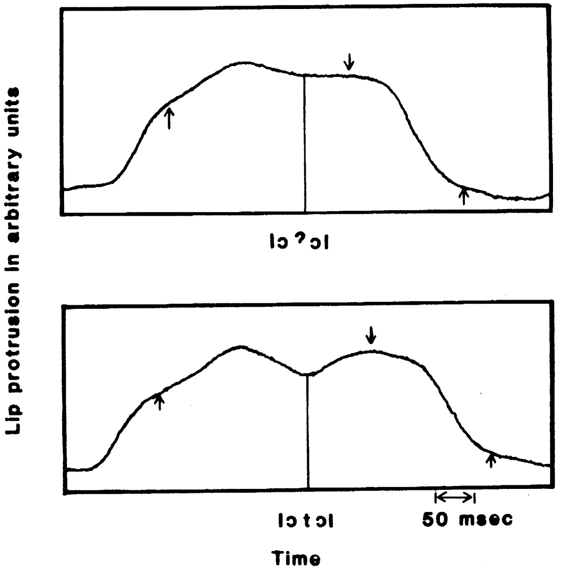

FIGURE 2. Output of a strain gauge transducer on the lower lip for the syllables [lɔʔɔl] and [lɔtɔl]. The trace shows the forward movement of the lips for rounding during vowel production. Coordinate values increase for greater forward movement of the lip. Line and arrows indicate the same acoustic events as in Figure 1.

a trough is some sort of a positive articulatory requirement for each phone for which it occurs. Such an approach is taken by Engstrand (1981); he suggests that the lip relaxation associated with [s] and [t] between rounded vowels may arise as a consequence of the aerodynamic prerequisites of these consonant sound types, rather than as a consequence of some general consonant property, or their syllabic position. Presumably, then, by analogy, lip relaxation fails to occur for sequences in which a glottal stop occupies the intervocalic position, because there is no acoustic requirement for such a maneuver. If the argument is accepted, we must then search for those acoustic requirements which specify the details of tongue position for a bilabial stop, in the environment of high front vowels. While it may seem, on the face of it, somewhat unparsimonious to search for two separate acoustic arguments for the appearance of a trough in the two environments, there is no *a priori* reason to discard the possible explanation.

Observations like those of this experiment substantially restrict the field over which we can apply any "theory" of coarticulation, or of syllabification. Nonetheless, we have ample evidence that the articulatory requirements of a given phone are at least broad enough to allow some contextual variation. It remains in the future, then, for us to develop a theory of syllabification and coarticulation using evidence gathered from the articulatory domain with a net of a mesh that has a smaller gauge than that which has produced our present views.

NOTES

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REFERENCES

Abbs, J. H., Gilbert, B. N., A strain gauge transduction system for lip and jaw motion in two dimensions: Design criteria and calibration data. *Journal of Speech and Hearing Research,* 1973, *16,* 248–256.

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

Bell, A., Hooper, J. B. Issues and evidence in syllabic phonology. In A. Bell & J. B. Hooper (Eds.), *Syllables and segments.* New York: Elsevier North-Holland, 1978.

Bell-Berti, F., & Harris, K. S. More on the motor organization of speech gestures. *Haskins Laboratories status report on speech research,* 1974, *SR-37/38,* 73–78.

Bell-Berti, F., and Harris, K. S. A temporal model of speech production. *Phonetica,* 1981, *38,* 9–20.

Bronstein, A. J. *The pronunciation of American English.* Englewood Cliffs, N. J.: Prentice-Hall, 1960.

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

Gay, T. Some electromyographic measures of coarticulation in VCV utterances. *Haskings Laboratories status report on speech research,* 1975, *SR-44,* 137–146.

Gay, T. Articulatory units: Segments or syllables? In A. Bell & J. B. Hooper (Eds.), *Syllables and segments.* New York: Elsevier North-Holland, 1978.

Heffner, R-M. S. *General phonetics.* Madison, Wisconsin: University of Wisconsin Press, 1949.

Jones, D. *An outline of English phonetics* (8th ed.). New York: Dutton, 1956.

Kiritani, S., Itoh, K., & Fujimura, O. Tongue-pellet tracking by a computer-controlled x-ray microbeam system. *Journal of the Acoustical Society of America,* 1975, *57,* 1516–1520.

Kozhevnikov, R. V., Chistovich, L. *Speech: Articulation and perception.* (Translated from Russian) Report 30, 543. Washington, D.C.: Joint Publications Research Service, 1965.

Ladefoged, P. *Three areas of experimental phonetics.* London: Oxford University Press, 1967.

MacKay, I. *Introducing practical phonetics.* Boston: Little Brown, 1978.

Malmberg, B. *Phonetics.* New York: Dover, 1963.

Pulgram, E. *Syllable, word, nexus, cursus.* The Hague: Mouton, 1970.

Stetson, R. H. *Motor phonetics: A study of speech movements in action* (2nd ed.). Amsterdam: North-Holland, 1951.