

REPRESENTATION OF VOICING CONTRASTS USING ARTICULATORY GESTURES*

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The representation of cross-language voicing contrasts has been a recurrent problem, since the mapping between phonological categories and their physical phonetic realizations is not one-to-one. Recently, Keating (1984) has argued that the representation of such contrasts for stop consonants must involve purely abstract features ([+voice] and [-voice]), which map onto phonetic categories for stops based on voice onset time (voiced, voiceless unaspirated, voiceless aspirated) in different ways for different languages. However, an articulatory analysis of voicing contrasts based on the presence or absence of glottal opening-and-closing gestures, as suggested in Browman and Goldstein (1986), may well provide a more nearly one-to-one mapping between phonological and physical categories. Moreover, as we shall show, such an articulatory analysis correctly predicts patterns of F_0 behavior that are wrongly predicted on the basis of purely abstract voicing categories.

Keating (1984) argues that if phonological features are constrained to be the same features as those used for phonetic representation, then certain cross-linguistic generalizations, involving voicing assimilation and correlations of voicing with vowel duration and pitch, will be missed. She demonstrates that the phonetic classes of voiced, voiceless unaspirated, and voiceless aspirated do not provide adequate cross-language natural classes for phonological rules. For example, both French and English have a voicing contrast, but different phonetic categories are involved. Whereas French (and sometimes English, in utterance-medial position) contrasts fully voiced [b,d,g] with voiceless unaspirated [p,t,k], English can contrast voiceless unaspirated [p,t,k] with voiceless aspirated [p^h,t^h,k^h] (in absolute initial position). Thus, the phonetic categories that contrast are not the same in the two languages. Nevertheless, as with many other languages, the vowels in both French and English are longer before the phonologically [+voice] stops than before the phonologically [-voice] stops (cf. Mack, 1982). Similarly, cluster voicing assimilation is found in languages regardless of whether the stops contrast in voicing or aspiration.

We suggest that Keating's abandonment of physically-based phonological features may in fact be unnecessary, and may simply reflect the wrong choice of physical descriptors. That is, a description in terms of articulatory gestures and their relative timing is, in fact, capable of accounting for the patterns Keating discusses. The basic phonological units in such an approach

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are articulatory gestures: organized patterns of movement within the oral, laryngeal, and nasal articulatory systems. Thus, as formalized in Browman and Goldstein (1986), voiceless stops can, to a first approximation, be represented as constellations of two gestures (an oral constriction gesture tightly coordinated with a glottal opening-and-closing gesture), while voiced stops can be represented as single oral constriction gestures. As originally suggested by Lisker and Abramson (1964), differences between aspirated and unaspirated voiceless stops can be captured directly by the timing between the two gestures in the constellation (or phasing: cf. Kelso & Tuller, 1985; Browman & Goldstein, 1986).

Voicing contrasts. In a gestural approach, the voicing contrast in both French and English is described as the presence vs. the absence of a glottal opening-and-closing gesture. In utterance-medial position, both French and English [-voice] stops typically show glottal opening-and-closing gestures, regardless of whether they are unaspirated (French, English) or aspirated (English). The [+voice] stops, however, do not display glottal opening-and-closing gestures in either language. This correlation between contrastive voicing and the presence vs. absence of glottal gestures can be seen for French in the data of Benguerel, Hirose, Sawashima and Ushijima (1978). For English, Lisker, Abramson, Cooper, and Schvey (1969) found that in running speech 96 percent of stressed /ptk/, 84 percent of unstressed /ptk/, and only 6 percent of /bdg/ were produced with glottal opening-and-closing gestures. Although the timing and size of the glottal gesture in English and French differ, the categorization of stops as [-voice] or [+voice] in utterance-medial position correlates quite well in both languages with the presence vs. absence of a glottal opening-and-closing gesture.

In absolute initial position, the glottis is already open (for breathing), and the opening portion of the glottal opening-and-closing gesture is, therefore, not actually observed. Thus, the relevant difference between [+voice] and [-voice] stops in this position is in the relative timing of the adduction of the vocal folds. Both French /d/ (Benguerel et al., 1978) and English /b/ (Flege, 1982) show glottal adduction well before stop release in utterance-initial position. Note that this is true for English (for eight of the ten speakers) regardless of whether there is voicing during the closure. That is, both phonetically voiced and voiceless unaspirated /b/ can show the same pattern of glottal adduction. Thus, a physical characterization using articulatory gestures appears to capture the voicing contrast in English and French for utterance-initial as well as utterance-medial position.

Vowel length. The simplest, and strongest, claim in a gestural approach is that vowel length differences will be correlated with the absence (longer) and presence (shorter) of a glottal opening-and-closing gesture. For those languages on which both glottal and durational data are available, the strong claim appears to hold up. French and English, as discussed above, are clear examples. Dutch (Slis & Cohen, 1969), Swedish (Lindblom & Rapp, 1973), and Korean (Chen, 1970) all display the vowel length difference, and available data suggest that the contrast for these languages can be described as the presence vs. absence of glottal gestures: Dutch (Slis & Damste, 1967) and Swedish (Lindqvist, 1972) both contrast [-voice] stops that have glottal opening-and-closing gestures with [+voice] stops that do not. Korean presents a slightly more complicated case in utterance-initial position, but in the intervocalic environment relevant to the vowel length rule, the same pattern is found (Kagaya, 1974).

Voicing assimilation. In a gestural approach, assimilation of a cluster in favor of the voiceless member can be described as a rule specifying the overlap of a single glottal gesture with two oral gestures. Assimilation in favor of the voiced member would be described as glottal gesture deletion. Thus, the gestural approach can account for voicing assimilation rules quite naturally.

F₀ patterns. Keating (1984) also discusses the relation between voicing contrasts and F₀ patterns. In many languages, the F₀ pattern on vowels following [+voice] stops is low and rising, while that following [-voice] stops is high and falling. Keating presents evidence from Hombert, Ohala, and Ewan (1979) that the F₀ patterns on the vowels following stops in French and English are similar. The F₀ following /ptk/ in either language shows a high falling pattern, while following /bdg/ it shows a low rising pattern. The F₀ difference is thus seen by Keating as reflecting the underlying abstract status, rather than the phonetic realization, since in the data of Hombert et al. (1979), English /bdg/ and French /ptk/ fall together phonetically as voiceless unaspirated. However, we can once again associate the similar behavior of French and English with the fact that for both languages, the [-voice] stops have a glottal opening-and-closing gesture while the [+voice] ones do not.

The relation between voicing and F₀ in Danish provides the most interesting comparison of the abstract and gestural analyses. In Danish, there is a contrast in initial position between aspirated and unaspirated stops. Unlike other contrasts described so far, however, both stops show glottal opening gestures (Frøkjær-Jensen, Ludvigsen, & Rischel, 1973). (The unaspirated stops have smaller glottal gestures and are timed differently.) Keating's abstract analysis predicts that Danish should behave like English and French in showing a high falling F₀ pattern following [-voice] stops and a low rising pattern following [+voice] stops, since all three languages contrast [±voice] stops. A gestural analysis predicts that, on the contrary, the Danish stops, both of which have glottal gestures, should both show high falling F₀ patterns. The gestural analysis, therefore, predicts that Danish will be unlike French and English, which contrast presence vs. absence of glottal gestures. Petersen's (1983) study of F₀ following initial consonants in Danish supports the prediction based on the gestural analysis. The F₀ patterns following aspirated and unaspirated stops are the same--high and falling (with a pitch difference averaging only 2 Hz). Moreover, the Danish consonants examined that do not have glottal opening-and-closing gestures (/v/ and /m/) show a low rising F₀ pattern. While these results must be treated with some caution, as other studies of Danish have revealed larger F₀ differences between aspirated and unaspirated stops (Jeel, 1975), nevertheless Petersen's study provides clear evidence for a correlation between glottal gestures and F₀ patterns, rather than between abstract voicing categories and F₀ patterns.

Thus, analysis of cross-linguistic voicing contrasts in terms of glottal opening-and-closing gestures accounts for the similarities between languages as well as or, in the case of F₀ patterns, better than the purely abstract analysis posited by Keating. In addition, the articulatory analysis captures the facts of articulation directly, rather than requiring an additional set of mapping functions.

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