CONTROL MECHANISMS OF TONGUE DORSUM ACTIVITY IN SPEECH PRODUCTION

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ABSTRACT

This paper shows that relevant information about the mechanisms of tongue dorsum control may be obtained through a measure of acoustic and articulatory variability. The data reported here indicate that coarticulatory effects for tongue dorsum activity decrease with an increase in the degree of mediopalatal constriction, an increase in the number of vocal tract constrictions, and an increase in the duration of the temporal lag between two successive gestures in time.

INTRODUCTION

According to phonological theory (Halle, 1983) there is a one-to-one correspondence between phonetic segments and underlying phonemes in the systematic phonetic representation of a phonemic string. Such a representation consists of a sequence of discrete phonetic units composed of features specifying independently controlled articulatory states.

Recent phonetic research suggests however that the production of phonemes in running speech ought to be characterized in terms of articulatory gestures overlapping in time rather than in terms of articulatory states devoid of temporal specification (Brown and Goldstein, 1986). The rationale for such an alternative means of phonetic representation arises from the belief that the mechanisms underlying the speech production process are best captured by a gesture-based model than by a feature-based model. Moreover, as shown by the following examples, this appears to be the case for the activity of one articulatory gesture and of two articulatory gestures in sequence.

According to a feature-based model of speech production, rounded vowels in Swedish and American English are equally represented by means of the feature [+round]. Lubker and Gay (1982) have shown, however, that both languages differ as to the strategies that speakers use to execute lip rounding. This gesture is more extensive, shows less variability and is initiated earlier for Swedish than for American English speakers. Thus, contrasting strategies are required in order to execute lip rounding in the two languages in line with the fact that Swedish has a larger inventory of rounded vowels than English.

Experimental evidence also shows that the activity of different articulatory gestures is temporally organized during the phonetic realization of successive phonemes. According to McAllister, Lubker and Carlson (1974), lip rounding in Swedish is initiated earlier for high front rounded vowels than for back rounded vowels when they are preceded by the sequence [it]. It is possible that lip movement is coprogrammed with tongue movement in such a way that the delay in lip onset activity increases with the complexity of the tongue movement (larger for [itu] than for [ity]). Extrinsic timing theories of speech production (such as a feature-based theory) cannot account for such temporal relationships.

VARIABILITY AND ARTICULATORY CONTROL FOR TONGUE DORSUM ACTIVITY

The examples given above show that phonemes are produced by mechanisms that control spatial displacement and temporal organization of articulatory activity. This paper shows that information about these mechanisms can be inferred from a measure of articulatory variability. Thus,
for example, important aspects about the nature and degree of control on a given articulator ought to be predictable from changes in the activity of the articulator under consideration as a function of phonetic context and speaker.

To test this hypothesis I will report changes in tongue dorsum activity associated with
(a) the degree of constriction
(b) the formation of a single vs a double place of constriction
(c) the duration of the temporal lag between two successive articulatory events.

VARIABILITY ASSOCIATED WITH THE DEGREE OF CONSTRICTION

I will first account for data on phonetic variability following differences in the degree of tongue dorsum constriction at the mediopalate.

Articulatory and acoustic data (Recasens, 1984a, 1984b) indicate that the degree of context-dependent and speaker-dependent variability in the phonetic realization of palatal, alveolo-palatal and alveolar consonants changes inversely with the degree of mediopalatal contact. Data were collected separately for the following consonants in intervocalic position: palatal [j] (showing a high degree of mediopalatal contact), alveolar [n] (showing a low degree of mediopalatal contact), and alveolopalatals [p] and [t] (showing intermediate mediopalatal contact between that for [j] and [n]).

Articulatory data on linguopalatal contact for one speaker show that the effects of the vowel environment on the degree of mediopalatal contact for the consonants under discussion decrease as the degree of contact for the consonant increases. Thus, contextual variability is highest for alveolars and lowest for palatales, alveolopalatals falling in between. Acoustic data for several speakers show analogous effects across contexts and speakers, thus conforming to the articulatory data.

These data are consistent with analogous findings for other languages besides Catalan (the language tested in the studies above). Thus, low context-dependent variability has been reported for palatal consonants in American English (Lehiste, 1964; Stevens, House and Paul, 1966) and French (Chaffcouloff, 1980); also, considerable context-dependent variability was found for alveolar consonants in Swedish and English (Öhman, 1966).

It can be concluded that the tongue mediadorsum is subject to different degrees of control for the production of those consonants. This does not only apply to [n] (non palatal) vs [p] (alveolopalatal), [j] (palatal) but also to [p] vs [j]. It thus appears that articulatory control for [p] is directed towards the formation of a predorsoro-alveolo-prepalatal constriction, and that much of the mediadorso-mediopalatal contact follows automatically from the raising of the predorsum.

The production of [j], on the other hand, involves the activation of the predorsum and the mediadorsum towards the achievement of a prepalato-mediopalatal constriction.

This is a good example of how phonetic variability may change with modifications in the degree of control exerted on a given articulator to make a constriction.

VARIABILITY ASSOCIATED WITH THE NUMBER OF CONSTRICTIONS

Second, I will account for data on phonetic variability for phonemes involving two simultaneous places of articulation one of which requires the activation of the dorsum of the tongue.

Acoustic data show low vowel-dependent and speaker-dependent variability for consonants produced with two places of articulation, namely, the labiovelar [w] (which is articulated with a bilabial constriction and a dorsovelar constriction) and the velarized apicoalveolar [t] (which is articulated with an apicoalveolar closure, and a dorsovelar and/or dorsoapharyngeal constriction).

These data are consistent with acoustic data showing low F2 variability for [w] in American English (Lehiste, 1964) and French (Chaffcouloff, 1980), and for "dark" [t] in English (Bladon and Al-Banmerni, 1976).

It is suggested that low variability for these consonants results from the severity of the articulatory requirements imposed by speakers during the formation of two simultaneous places of articulation. For [w], the speaker must execute a back-and-up raising movement of the tongue dorsum while rounding and protruding the lips. For [t],
alveolar contact must be achieved with the apex of the tongue while raising the tongue dorsum towards the uvula and higher pharynx.

Evidence for this hypothesis stems from two sources. On the one hand, a higher degree of F2 variability was found for the vowel [u] than for the consonant [w] in Catalan (Recasens, 1985) and American English (Stevens, House and Paul, 1966). Since the vowel and the consonant involve the same gestures, differences in acoustic variability between the two result presumably from the fact that [u] involves less labial activity and less dorsovelar constriction than [w] and, thus, requires a lower degree of articulatory control.

On the other hand, a higher degree of F2 variability was found for "clearer" (less velarized) than for "darker" (more velarized) varieties of [l] in Catalan (Recasens, 1985) and British English (Bladon and Al-Bamerni, 1976). The two varieties may share alveolar contact; however, "clear" [l] is always articulated with less dorsal constriction at the back of the vocal tract than "dark" [l]. It is, thus, subject to less articulatory control and, therefore, is more sensitive to phonetic variability.

This is a good illustration of how phonetic variability is dependent on modifications in the degree of articulatory control when one vs two places of articulation are involved in the production of a given phonetic segment.

VARIABILITY ASSOCIATED WITH THE TIMING OF ARTICULATORY ACTIVITY

Third, I will account for differences in the temporal organization of consecutive articulatory gestures one of which involves tongue dorsum activity.

Articulatory data on linguopalatal contact (Recasens, 1984c) show that context-dependent variability in dorsopalatal contact is lower for clusters of alveolars [n] and [l] plus [j] (i.e., [nj], [lj]) than for alveolopalatals [ɲ] and [ʎ]. The two phonetic categories are produced by means of highly analogous gestures, namely, tongue-tip and/or tongue-blade raising towards the alveolar region, and tongue-dorsum raising towards the hard palate. They differ in that alveolar contact precedes palatal contact by a temporal lag of 15 to 100 ms for clusters while the two articulatory periods occur simultaneously for alveolopalatals.

Lower variability for clusters as opposed to alveolopalatals results primarily from control requirements to keep a fixed temporal lag between the actualization of alveolar contact and palatal contact. The tongue dorsum shows a more prominent mediodorsal constriction for clusters vs alveolopalatals in line with the temporal independence of the [j] component and is thus more resistant to coarticulation.

I believe this to be a good example of how phonetic variability may be affected by the severity of the constraints on interarticulatory timing organization.

CONCLUSIONS

As this paper has tried to show, phonemes and phonemic sequences are actualized by means of gestures involving specific mechanisms of articulatory control. The data reported here reveal that some knowledge about these control strategies can be gained from an analysis of the variability allowed by the activity of articulators such as the tongue dorsum. It has been pointed out that the measure of coarticulatory activity may be useful to gain a better understanding of the mechanisms used by speakers for the production of articulatory gestures.

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