STOP ASSIBILATION IN QUEBEC FRENCH; AN ANALYSIS BY ARTICULATORY SYNTHESIS

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ABSTRACT

This paper discusses the use of articulatory synthesis as a research tool for determining the relationship between phonetic data and phonological structure. Under the assumption that the mapping between phonological and phonetic representations is accomplished by rules of phonetic implementation we use a computational model to examine alternative accounts of the derivation of surface affricates in Quebec French. The model's behaviour is shown to parallel natural speech data.

1. INTRODUCTION

One of the defining characteristics of Quebec French is the surface reflex of coronal stops /t/,/d/ in the context of a following anterior high vowel /i/,/y/. Underlying coronal stops are realized as the assibilated affricates [t^s,d^z] in these contexts. Forms such as *dix* "ten" or *petit* "little" are typically realized as [d^{z}Is] and [pt^{s}i]. These forms are usually accounted for by rules of the form

/t/ ---> [t^s]/___{i,y}
/d/ ---> [d^z]/___{i,y}

Alternative accounts of the mechanism responsible for the derivation of these surface affricates have been proposed. The first is a phonological account which assumes that the forms [t^s], [d^z] are contour segments with dual feature matrices consisting of a stop and fricative components [4]. The second is a phonetic account which assumes that the fricative component of the surface affricate is the consequence of the transition gesture between the constriction location of the apico-alveolar stop and that of the following vowel [3,8].

An articulatory synthesis system [1], which uses phonological feature matrices as input and explicitly models feature/production relations, is used to examine the explanatory value of both hypotheses. In the next sections we give a brief description of the system and present details of our computational simulation of /t/ assibilation.

2. SYNTHESIS SYSTEM

The articulatory synthesis system which has been implemented consists of three major components: first a series of modules in which different phonological, phonetic and articulatory knowledge structures are represented; an articulatory model [9]; and finally a central representation structure which controls modules interfacing and is accessible to the user.

We assume a multidimensional non-linear representation of underlying phonemic and phonetic segments, with fundamental distinguishing properties: (1) phonological features are assumed to be abstract binary classificatory features, i. e. segments may be [+/- labial]; while phonetic features are n-ary [x], i.e. [+labial] phonological segments may correspond to either [projected], [neutral] or [retracted] labial positions. (2) Phonological representation is assumed to be underspecified; that is, only contrastive feature values are marked underlyingly. Redundancy rules add essential feature values. (3) Physiological representation is in the spatial domain; therefore the phonetic/physiology passage defines a relation between discrete phonetic parameters and acoustically important area-function parameters [5].

Rules written in Delta account for internal properties and module interfacing [6]. The phonological rule-set assigns initial feature specifications and defines feature alignment relations. Phonetic rules translate abstract phonological representations into n-ary phonetic features and assign inherent duration to each segment. Rules of the physiological module account for phonetic feature/production relation by specifying corresponding motor-sensory goals and intrasegmental dynamics. The calculation of articulatory trajectories is accomplished by optimization techniques.

3. ACCOUNTING FOR /t/ ASSIBILATION

The system which we have described allows us to explicitly examine the phonology-phonetics interface question as the implementation of physiological gestures derived from a sparsely specified abstract feature representation and to test linguistic hypotheses about levels of representation. We illustrate this issue by modelling /t/ assibilation in Quebec French.

The properties of our computational model (which simulates the properties of actual articulatory systems) permit us to address two aspects of the assibilation problem: (1) do the articulators, during the transition gesture form /t/ to /i/, occupy for a critical duration a location which permits assibilation?; (2) does delayed glottal adduction following offset of closure result from speaker control or aerodynamic conditions of the post /t/ constriction?

3.1 Acoustic Data

A corpus of natural speech was gathered from a single speaker. Three types of stimuli were included in the data-set: (1) occurrences of /t/ followed by (a) a vowel which conditions assibilation, (b) vowels which do not; (2) occurrences of /t/ followed by /s/ in the same vocalic contexts; (3) occurrences of /s/ not preceded by /t/.

From these data we defined the duration for the various segments. We also found that while durations for vowels and fricatives vary under stress, durations of plosives remain constant.

3.2 Radiographic Data

X-ray tracings of /t/ when followed by /i,y/ were analyzed in order to gather data on articulatory gestures [10]. These data suggest that speakers do not aim at a particular target during assibilation, rather that the transition of the tongue is made directly from the /t/ to the /i/. This information on the motor-sensory goals was integrated into the physiological module.

3.3 Experiment

The input strings, such as, /ati/ and /atsi/ were submitted to the system. There were no specific rules provided to account for assibilation. The rule set did not include any rule inserting a fricative segment between the stop and the following vowel. Further, the rate of occlusion offset was set to be uniform for all vowels, and glottal aperture duration did not depend on consonant type.

The synthetic response produced an excrescent fricative segment between the stop and the vowel. The spectrograms of synthesized sequences replicate the major characteristics of measured sequences taken from natural speech. Figure 1 shows the spectrogram of the synthetic sequence derived from the /ati/ input string. Frication noise is found between 3 and 8kHz.

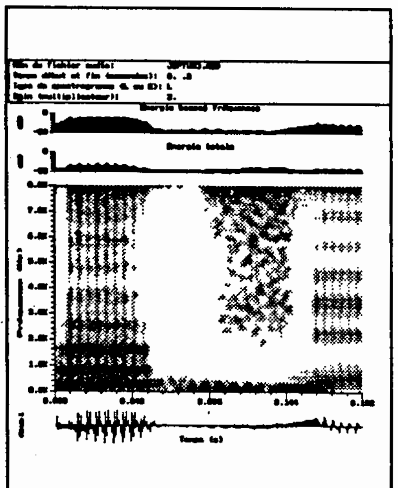

Figure 1 /ati/

The measured durations for the vowels and the frication noise correspond well to those that are stipulated in the rules (cf Table 1). The durations for /t/ are smaller than expected, because they refer only to the period of occlusion, and do not include the transition of the vowel to the onset of closure. Assibilation was produced even when the vowels /e/ and /a/ followed the /t/. However, the spectrogram reveals that the initiation of vocal cord vibrations was quicker than after high front vowels, giving frication periods inferior by 6 to 14%.

TABLE 1. Acoustic durations

Sequence	Duration (ms)			
	prec. vowel	/t/	fric.	foll. vowel
/a ti/	48	49	47	37
/a ti/ acc.	48	48	46	67
/a tsi/	48	47	141	46
/a tsi/ acc.	48	46	162	69
/a ty/	48	49	46	37
/a te/	48	46	44	41
/a tɑ/	48	61	41	39

4. CONCLUSION

The explicit modelling of hypotheses on the mechanism of assibilation has allowed us to evaluate their likelihood. We find that it is not necessary to program assibilation as a phonological process: it results from aerodynamic conditions that are satisfied during the course of the transition form /t/ to /i/, as a consequence of voice onset delay.

These results, however, should be interpreted in the light of traditional warnings on the use of simulation techniques. For they depend on the validity of the model and the articulatory synthesizer that are evidently an approximation of reality [2].

Further tests should be carried out with a full range of vowels. However it would appear that the computational model can be of further use to research in linguistics to test theories.

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