ACOUSTIC CORRELATES FOR PLACES OF ARTICULATION IN SPANISH STOP CONSONANTS

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ABSTRACT

This work aims at an acoustic description of Spanish plosives. A corpus of utterances taken from fluent speech has been spectrographically analyzed. The results confirns that there are invariant acoustic properties for place of articulation in Spanish plosives. These properties have been found in the first ms of the consonant. They are context independent and can be used so distinguish between places of articulation.

1. INTRODUCTION

The study of invariant acoustic properties present in the phonic chain is one of the main subjects in the research that is taking place at present in the field of phonetics. Stevens and Blumstein have formulated a theory of acoustic invariance that claims that invariance is the result of series of acoustic properties that encompass several components of the sound wave: "/.../ acoustic invariance corresponding to a particular phonetic category or distinctive feature resides in the acoustic signal /.../ but rather is provided by integrated acoustic properties that may encompass several of these components" (Stevens, Blumstein, 1981).
The idea that integrated acoustic properties which manifest themselves in an invariant manner for each place of articulation exist, is accepted in the theoretical development of Stevens and Blumstein. Several researchers had already suggested (Cole, Scott (1974); Stevens (1975); Fant (1973)) that integrated properties associated with a phonetic feature are invariant from an acoustic point of view, that is to say, they are independent of the context in which the feature is produced. According to Stevens and Blumstein (1978) the invariant cues of the place of articulation can be characterized regarding the spectrum at a given moment rather than variations through time, as for example, transitions. Thus, a consequence of formant positions and burst characteristics, the spectrum, taken between 10-20 msec. after the explosion of the plosive way show different characteristics for each place of articulation.
The present study follows this line, and concentrates on Spanish plosives. Its aim is to determine, from an acoustical analysis the invariant elements of the sound wave that might characterize the three different places of articulation.

2. CORPUS

Our corpus of analysis is consists of 200 sentences 8 syllable in which [p t k] always appear in the penultimate syllable which is also the one in which stress falls. This structure has been chosen because it corresponds, in number of syllables and stress position, to the normal structure of Spanish (Navarro Tomás, 1941).
It must be emphasized that the corpus analyzed comprises fluent speech sentences. This is an important fact since the characteristics of speech sounds vary according to the type of statement in which they are inserted (Shoup, Pfeiffer, 1976).
The realizations of [p t k] always appear in VCV sequences, where C represents the allophone which is being studied and V each of the vowels of Spanish.
The corpus has been realized by 6 informants, 4 male and 2 female speakers, without strong dialectal features (standard). For the recording, we have used the method of inserting the utterance to be analyzed into a "sentence-frame" the structure of which is: "He said in a quiet voice: "————", and left".

3. EXPERIMENTAL PROCESS

Utterances have been recorded in an anechoic chamber, with an UHER 4000 Report-L and Uher M-514 microphone. Afterwards, the corresponding

spectrograms have been made with a Voice Print series 7000 sonograph, in broad band and with a linear range of 5000 Hz at the most. Data corresponding to burst, VOT and transitions have been taken out from all these recordings.
The values thus obtained, which correspond to 1200 Spanish utterances, have been subjected to a computerized treatment by means of the SPSS (Statistical Package for the Social Siences).

4. RESULTS

4.1. Burst

The characterization of burst in spectrograms has been realized regarding its duration and the range of frequencies in which its energy spreads. The results obtained show that the values that burst duration reach are similar in male and female voices and also in the different vowels that follow [p t k]. It seems that stress does not affect this acoustic cue either. On the other hand, there is a difference between the values for average duration which have been obtained in each plosive:

- average duration [p]: 15,384 msec.
- average duration [t]: 15,267 msec.
- average duration [k]: 21,868 msec.

The burst of [k] is 29,65% longer than that of [p], and 28,539% longer than that of [t], the difference between [p] and [t] being very small.
From the point of view of the frequences over which energy's spread, for all plosives, the energy of burst is found in a band of frequencies of about 200 Hz. that ranges from 800 Hz. to 1000 Hz. in 65-70% of the utterances. Bursts next to front vowels have a tendency to initiate the energy in bands of frequency which are more acute than bursts beside back vowels, although, in both cases, the significant band is still the one between 800 and 1000 Hz. In respect of the end of burst energy, the limit for [p] lies between 1200 Hz and 4000 Hz. in 86,146% of the utterances. For [t] burst energy ends between 2200 Hz and 5000 Hz. in 93,733% of the cases. And, finally, for [k], between 1200 and 3500 Hz. in 85,443% of the utterances. In this latter case the energy is concentrated between these limits, unlike the cases of [p] or [t] the limits of which can reach 4000 Hz., or even in the case of [t], to 5000 Hz., as mentioned above.
There is a clear difference in duration and concentration of energy for [k] as opposed to the other two plosives.

4.2. VOT

The values obtained for the VOT of [p t k] regarding the different elements of variation have been the following:

- [p]: 17,182 msec.
- [t]: 19,757 msec.
- [k]: 30,014 msec.

although there is an increasing progression between the values for [p] and [t]. It is true that the difference is very small. This is not the case the value of the VOT of [k]. The VOT for [k] has a duration 40,78% greater than that of [p] and 31,905% than that of [t].

4.3. Transitions

Spectrographic representations only show a "continuum" of energy in movement it being difficult or even impossible to establish a border line between "transition" and "formant". And even more if we deal with fluent speech. Therefore, we have decided to determine the tangent between the point where vowel energy begins and the frequency value that has been obtained 20 msec. after the beginning of the vowel. The tangent provides information about the degree of slope of formants at every point under consideration making it possible to measure formant directions and the degree of inclination of slopes.
The results show that the values of the tangents of F1 are always smaller than those of the tangents of the other formants. The slopes are always more marked for F2. The values of the tangents of F3 are always intermediate between those of F1 and F2.
The values of the tangents are always greater when the vowel follows the plosive rather than preceeding it.
The values at which the tangents of the formants for front vowels preceded or followed by back vowels are higher than those arrived at when the preceeding of following vowel is a front vowel. This implies that the slope of the formant is more marked in phenomenon can occur: the value of the tangent is higher for back vowels when the preceeding or following vowel is front, in which case, slopes are also more marked. This fact leads us to cunclude not that the direction and the value of the slope do not depend only on the contoid under consideration, that is to say

on the place of articulation, but also on the vowel that precedes or follows the plosive.

The slopes for the formants adjacent to [p] are the only ones that always take the same direction: descendent in all cases. Those of the formants for the vowels adjacent to [t] follow no regular pattern in the case of F1. As for as F2 are concerned, slopes are, in general, descendent when the vowel is front and ascendent when the vowel is back. The slopes of F2 are usually descendent with many exceptions. The F1 slopes for [k] have no regularity and, although in some cases F2 and F3 tend to converge, this is not the general trend so, in relation to transitions, to establish regularities for a velar place of articulation is practically impossible.

5. DISCUSSION

As the results that have been obtained are centered upon the analysis of the behaviour of approximately the first 35-40 msec. of the beginning of plosives, we can make a comparison between these and the results that Stevens and Blumstein have obtained. Their fixed window of analysis of 26 msec. includes practically the same consonantal segment than the one analyzed in this study. For these authors, the spectrum of the velar place of articulation presents more amplitude in high frequency peaks, and the energy is distributed over the entire spectrum. In the results obtained for Spanish consonants, the dental-alveolar one presents the larger distribution in the energy spectrum of the burst and second formant transitions, above, tend to go towards the high zones of the spectrogram thus these data seem to coincide with those of Stevens and Blumstein. According to these authors would give rise to a spectrum in which the frequencies with greater amplitude are the lower ones (a labial place of articulation). In our corpus, this place of articulation shows a smaller amount of diffusion of burst energy than for [t], the minimum values of VOT and a regular tendency of transitions to go to the lower zones of the spectrum such as Stevens and Blumstein propound. Finally, for a velar place of articulation, for which in Spanish the VOT has a longer duration, the data obtained also coincide with those of Stevens and Blumstein who propound a compact spectrum for [k]. In our case, although transitions do not show any regularities, burst energy does, as it is always concentrated in an intermediate zone of the range of frequencies (compact spectrum) and also, as already mentioned, the VOT.

6. CONCLUSION

Viewed from the theory of acoustic invariance, the data which have been obtained in this study for Spanish plosives, allow us to state that there is indeed a series of integrated acoustic properties (not only one) that manifest themselves in an invariant manner for each place of articulation. These properties seem to manifest themselves in the first msec. from the beginning of the burst to the onset of voicing corresponding to the vowel.

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