

THE MAIN CUES DIFFERENTIATING ASPIRATED AND  
UNASPIRATED STOPS AND AFFRICATES IN ARMENIAN

AMALIA KHACHATRYAN

ALBERT AIRAPETYAN

Institute of Linguistics  
Armenian Academy of Sciences  
Yerevan, USSR, 375001

Depart. of Radioengineering  
Polytechnical Institute  
Yerevan, USSR, 375009

The purpose of this paper is to further examine the nature of aspirated and unaspirated stops and affricates of Armenian presenting new data and re-evaluating the VOT as the only cue for differentiating these two categories of sounds. Generalized VOT + K I parameter is suggested for reliable distinction of both groups of sounds.

## INTRODUCTION

During the last two decades aspiration has attracted the interest of phoneticians in many countries. This is partly due to the use new methods of articulatory investigation, such as electromyography, glottography, fiberscoping alongside with the more traditional acoustic ones, such as spectrography, oscillography.

This increase of interest is partly upheld by the cross-language study of aspiration in stops carried out by L. Lisker and A. Abramson, who have suggested a new cue - voice onset time ( VOT ) for discriminating the three categories of stops - voiced, voiceless and aspirated (1). Aspiration has been studied from different aspects: its theory (2), mechanisms

of production (3), its glottal and supra-glottal articulation timing (4), its relationship to other phonetic features, such as fortis/lenis (5), acoustic expression and perception.

It has been mentioned that in such languages as English and Swedish, aspiration being the expression of lenis/ fortis feature is concomitant and differentiates voiced and voiceless stops. In Danish it is the only distinguishing feature between the sets ptk and bdg.

It is worth mentioning that the first experiments in voice timing in stops were carried out by H. Adjarian at the Rousselot laboratory as far back as 1898 (7). His kymographic tracings were published in the journal "Revue internationale de Rhinologie, Otologie, Laryngologie et Phonétique expérimentale" in 1899 and were furnished with Rousselot's commentaries. Yet the purpose pursued by the author was somewhat different from nowadays studies. Adjarian intended to show the gradual development of devoicing (lénition) which in the long run brought to the shift of voiced stops and affricates of Old Armenian into voiceless ones in many modern dialects and vice versa. Thus Adjarian paid attention to the fact, that in some dialects the voicing of b, d, g, j, ʃ may lag a little, in others still more, whereas in some others - too much, which has brought to the shift of voiced consonants into voiceless aspirat-

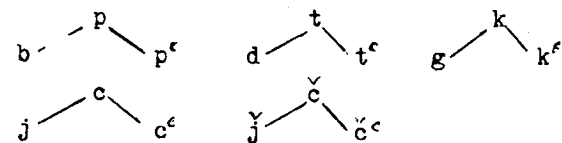
ed ones. Actually, from the phonological point of view this difference is one of the major phonetic differences existing between Eastern and Western dialects of Armenian as well as between the two literary variants.

A new impulse to the study of this feature was given by Leigh Lisker and Arthur Abramson, who carried out cross-language experiments and a more detailed examination of this variable terming it VOT. This cue proved to be valid to distinguish the three main categories of stops: a) those with voice lead (fully voiced b d g), b) with short-lag voice (voiceless p t k) and c) with long-lag voicing ( aspirated p t k). The authors showed the validity of this variable as compared to fortis/lenis or voiced/voiceless features used by most linguists. Of particular interest for us is that the author's investigation included the data concerning Eastern Armenian literary language.

Our first spectrographic experiments in consonants of Armenian were carried out in late 60-ies in Tallinn at the Institute of Language and Literature. Even the limited data we got brought us to the conclusion that the distinction between aspirated and unaspirated stops of Armenian was bound primarily to the duration of release, which later on came to be known as voice onset time - VOT. But since our primary purpose was to prove the monophonemic nature of aspirated stops as opposed to the traditional view that considered them compound ones consisting of one stop and the glottal fricative [h], we were interested in other features as well, particularly the timing relationship between the closure and release and the total duration of both series of consonants (6). A reverse relationship between closure duration and release time has been established.

#### LINGUISTIC MATERIAL

Unlike English and some Western European languages, in which aspiration is a redundant feature, in Eastern Literary Armenian it is an independent distinctive feature differentiating homorganic stops and affricates. Aspirated sounds form oppositional pairs with unaspirated voiceless cognates in all positions in monosyllabic and disyllabic words. Thus the Armenian stops and affricates can be presented in the following way:



In some dialects the fourth series has been claimed to exist by some linguists, but these sounds have been proved to have no phonological value, being only allophonic by nature and quite distinct from aspirated voiced sounds of Hindi.

In the first series of experiments monosyllabic or bisyllabic words with aspirated stops and affricates were used. They were presented to the speakers either in oppositional pairs or independently embedded in the carrier sentence "Sa ...e" 'This is ....'. The list of words included such words as payt - p'ayt 'horseshoe' - 'wood', tar - t'ar 'letter' - 'stack', akama - ak'ayay 'unintentional' - 'cock', cec - c'ec 'beat' - 'moth', čanč - č'anč 'fly' - 'palm', etc.

In the second series of experiments we chose words in which the phonemes under examination were in most unfavourable conditions for the realization of aspiration, such as unstressed syllables, words, in which aspirated stops were preceded by fricatives [s] or [š], in words with two or three aspirated sounds. The stimuli were pronounced at a normal rate.

#### METHOD

A computer integrated distinctive feature analysing device was used with subsequent segmentation of speech signal into elementary segments corresponding to speech sounds. The accuracy of segmentation was being controlled visually on the screen of the display. The time quantization is equal to 10 milliseconds (ms). The release time (VOT) of stops was measured according to sampling intervals. The intensity of the noise above 2000 Hz was measured on logarithmic scale.

6 male and 4 female native untrained speakers of Armenian served as subjects for this experiment. The stimuli were read into microphone being directly put into the analyser.

#### RESULTS

We were mainly concerned with differences of VOT and intensity of noise in aspirated and unaspirated stops and affricates. Though we did not pay special attention to the duration of burst, but certain differences which relate to place of articulation will also be mentioned. Thus the duration of burst in labial plosives is 5 - 10 ms, in dentals - 15-20 ms, and in velars - 30-35 ms. In aspirated cognates this burst is followed by noise of considerable duration, which varies in different phonetic contexts. Thus it is the longest in the final position, it is very strong and long initially and short in the middle position.

In fig. 1 the scatter diagram of VOT values on a single timeline is presented for aspirated and unaspirated stops. It shows that VOT as a whole differentiates between the two categories of stops. There is some overlapping of ranges in velar k - k' stops, which hampers the reliable

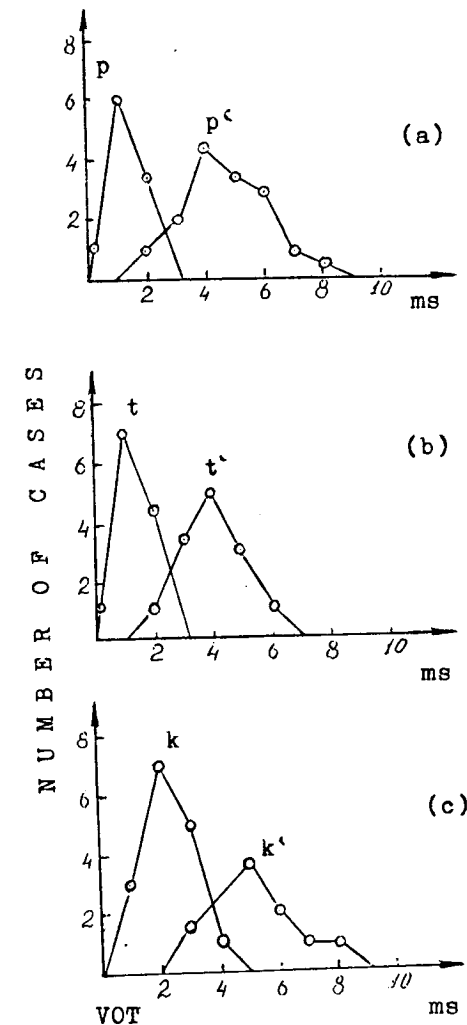


Fig. 1 The scatter diagram of VOT on a single timeline for unaspirated and aspirated stops (a) labials p - p'; (b) dentals t - t'; (c) velars k - k'.

distinction of these stops - a matter of no less importance in automatic segmentation of speech sounds. From this point of view the overlap of the ranges of VOT in aspirated and unaspirated affricates (in Armenian linguistic tradition terms) is very typical. In fig 2 the scatter diagram of VOT in affricates shows the degree of overlap. It is quite evident that VOT alone is not sufficient for

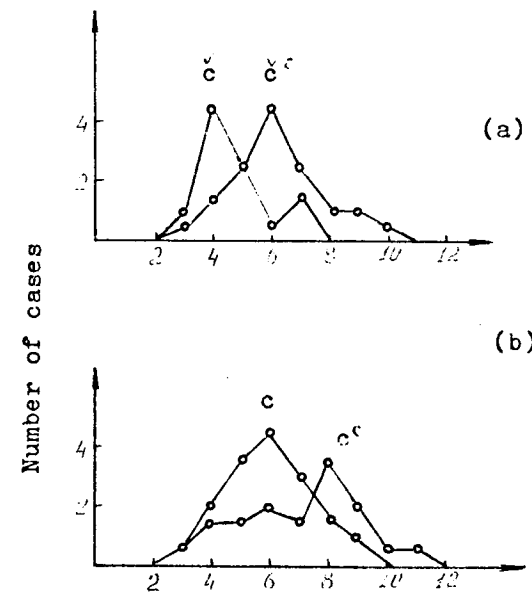


Fig. 2. The scatter diagram of VOT on a single timeline for unaspirated and aspirated affricates: apical c - c<sup>c</sup> (a), palato-alveolar č - č<sup>c</sup> (b).

their distinction. For reliable discrimination of these consonant categories an additional parameter is necessary. The intensity of friction noise which characterizes the release of stops and affricates may serve as such a parameter. In fig. 3 a two-dimensional scatter diagram of VOT and Intensity (I) for the aspirated and unaspirated affricates is plotted. The dots present unaspirated stops and the circles - corresponding aspirated ones. Though VOT may serve as a cue for differentiation of these categories of stops,  $p^t k$  and  $p^c t^c k^c$ , which corresponds to the division of the planes by the line parallel to the abscissa axis, there is a noticeable correlation between VOT and intensity, and an oblique line separating them increases the reliability of differentiation.

If in the case of aspirated and unaspirated stops the intensity cue is redundant or additional, in the case of affricates it is indispensable, as important

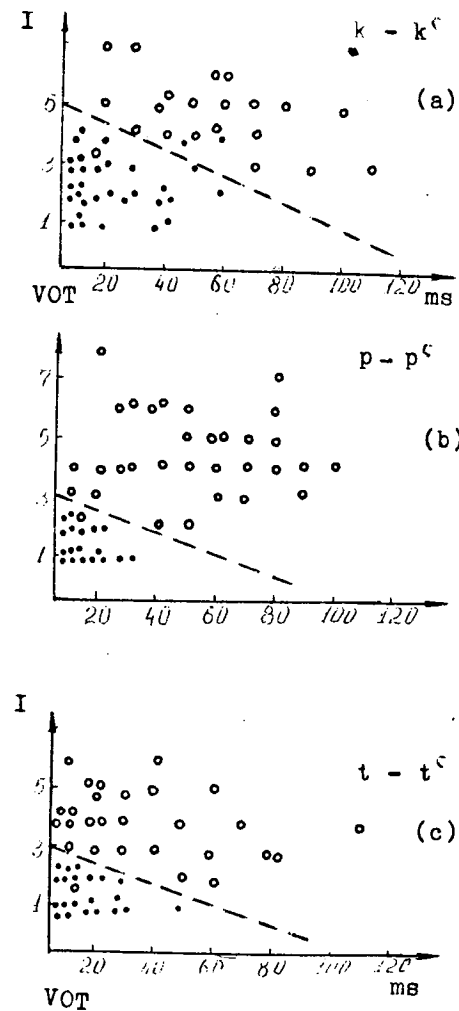


Fig. 3. A two-dimensional scatter diagram of VOT measurements and intensity values of stops: k - k<sup>c</sup> (a), p - p<sup>c</sup> (b) and t - t<sup>c</sup> (c). The dots indicate unaspirated sounds, circles - aspirated ones.

as VOT. In fig. 4 a two-dimensional plot distribution of VOT and intensity values of aspirated and unaspirated affricates is given. There is a clear-cut correlation with linear regression of VOT and intensity with the corresponding line separating the two areas. The equation of this correlation is as follows:

$$VOT + K I = C$$

where K and C are scale coefficients de-

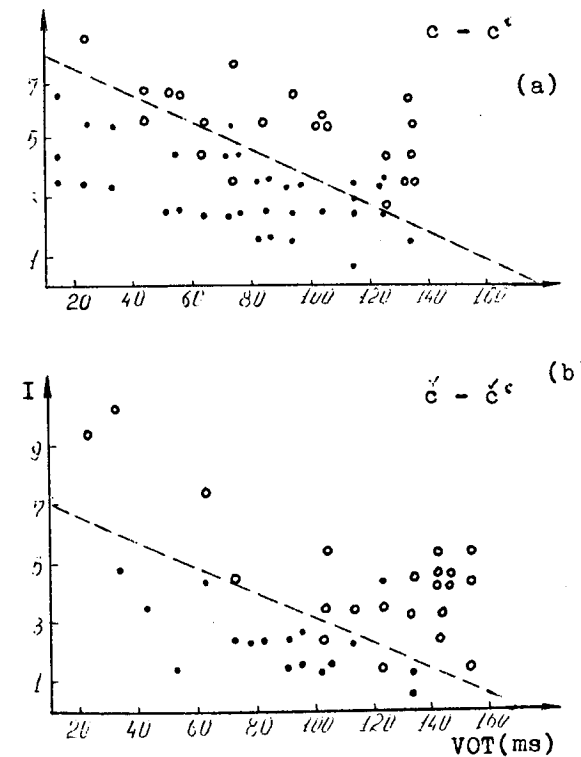


Fig. 4. Two-dimensional scatter-diagram of VOT and intensity values of affricates c - c<sup>c</sup> (a) and č - č<sup>c</sup> (b). The dots indicate unaspirated sounds, and circles - aspirated ones.

defined by the sensitiveness and dynamic range of intensity measurement channel. In our experiments  $K = 0,05$ , and  $C = 6$ . The parameter  $VOT + KI$  may be considered as generalized cue characterizing the degree of aspiration in aspirated stops and affricates.

#### CONCLUSION

It is obvious that acoustic differences of aspirated and unaspirated stops are bound primarily with the parameter VOT. Among different local stops VOT is most valid for differentiating labials p - p<sup>c</sup> and dentals t - t<sup>c</sup>. It is somewhat less valid for k - k<sup>c</sup> pair. For the affricates

the variable VOT is an ambiguous cue for discriminating the voiceless and aspirated categories. For differentiating them the parameter I (intensity of noise above 2000 Hz) is as important as VOT. Moreover there is an essential correlation between both cues, and the use of only one of them is not sufficient for their differentiation. It has been shown that a reliable accuracy of discrimination between aspirated and unaspirated stops and affricates is ensured by the generalized VOT + KI cue. The voiced correlates of both stops and affricates are distinct, since in their production F<sub>0</sub> is mostly present.

#### REFERENCES

1. L. Lisker and A. Abramson: A Cross-Language Study of Voicing in Initial Stops: Acoustic measurements, Word 20, 384-422 (1964).
2. Chin-Wu Kim: Theory of Aspiration. *Phonetica* 21, 107-116 (1970).
3. M. Halle and K. Stevens; A Note on Laryngeal Feature, MIT Quart. Prog. Rep. Res. IX. Speech Communication (1971).
4. B. Hutter: Vocal Fold Adjustments in Danish Stops. *Phonetica* 42, 1-24 (1985).
5. Р. Якобсон, Г. Фант и М. Халле. Введение в анализ речи. В кн.: Новое в лингвистике, вып. II, М., Изд. иностр. литературы, 1962, с. 207-208.
6. А. А. Хачатрян и В. Н. Айрапетян. Экспериментальное исследование согласных фонем современного армянского языка. Ереван, 1971.
7. Н. Аджарян, Les explosives de l'ancien Arménien étudiées dans les dialects modernes. *Revue internationale de Rhinologie, Otologie, Laryngologie et Phonétique expérimentale*, 1899, Paris.