ASPIRATED VS. NONASPIRATED STOPS AND AFFRICATES IN STANDARD CHINESE

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ABSTRACT

The distinction between aspirated and non-aspirated consonants in Standard Chinese (SC) is usually described in traditional phonetics as a difference in force or glottis opening. Our experiments, including acoustic analysis, manometers measurements and perception tests with synthesized consonants, revealed that information about aspiration is carried by prolonged turbulence with different features.. The perceptive cues for aspiration in affricates also depend upon the tongue positions of the following vowels: when before a low vowel, the aspiration is realized as a fricative /h/ immediatly following the releasing noise, while before a high vowel, it is realized as the prolongation of the releasing noise.

INTRODUCTION

In Standard Chinese, there are two groups of consonants which can be produced both with and without aspiration. These are the voiceless stops and affricates, each of which is distinguished from its counterpart in the feature aspirated/non-aspirated in the Chinese phonology.

In many European languages, e.g. English, the aspiration of word initial stops is only a conditional feature, but in many tone languages, especially in Chinese, it is a phonemic feature. In traditional Chinese phonetic works, the nature of aspiration is mostly discribed in terms of the force of articulation: the aspirated consonants having greater force of articulation than the non-aspirated ones. One of the popular phonetic outline books stated, "In aspirated articulation, the air stream expelled from the mouth cavity is stronger than in non-aspirated articulation.[1] It is also mentioned here and there that "an air-flow after release is called aspiration", that "the air-flow in non-aspirated sound is weaker and shorter, and vise versa, and that "for an aspirated sound, the glottis is opened during release, the air pressure is large and the air-flow breathing out is obvious", etc.

In recent decades, thanks to the widely application of phonetic experimentation, phoneticians can stucy the problems of aspiration more deeply, and the veil of non-aspirated/aspirated distinction are now being raised gradually. Many techinics have been used for investigating this feature in the levels of articulation, acoustics and perception. The VOT features of aspirated/ non-aspirated oppositon was examined in spectrograms and was proved by perception tests as an important cue[2],there were also investigators dealing with the glottic movements, air-flow rates, and nerves activities. Those studies have brought the discussion of aspiration to a high level.[3]

This paper intends to make further studies on the non-aspirated/aspirated consonants in Standard Chinese in order to raise and answer the following questions:

1) Which is the main perceptive cue for aspiration, the air-stream force, the duration or VOT, or the glottis opening?

2) What are the articulatory processes of these consonants?

3) Are there any different aspiration features between stops and affricates?

EXPERIMENT

Early in 60's we tested all the SC consonants, spoken by two speakers, a male and a female, of the Beijing dialect, using a level recorder (type: BK 2304) to measure the amplitudes and the length of the consonantal segments. The amplitude represents the overall acoustic pressure and the length was measured from the release point to the starting point of vowels.

For measuring the concentration area of noise and the VOT as well as the transition cue in stops and affricates, a Kay sonagraph of model 7029 was used. The amplitude were measured immediately after the release. The materials were spoken by a male Beijing native.[4]

Two sets of manometers were used to

measure the supra-glottis air-pressures and air-flow rates, the equipments were constructed by Professor Peter Ladefoged. [5] Thanks to the Department of Linguistics at UCLA, the experiments were done in their lab by Dr.H.M. Ren. Two informants,a male and a female, were asked to pronounce all the stops and the affricates in Standard Chinese, each followed by three vowels, high or low.

For the perception test, a number of non-aspirated and aspirated stops and affricates were synthesized by a syntnetic system designed by the phonetics laboratory of the Institute of Linguistics, Chinese Acacemy of Social Sciences.[6] Selected samples of spectrograms were made of the synthesized syllables.

For comparison, we made several spectrograms from Miao language in Guizhow and Bai-ma language in Tibet, which have aspirated fricatives in contrast with non-aspirated fricatives, in order to examine the nature of the aspiration noise. The materials were kindly supplied by the Institute of Nationalities, Chinese Acacemy of Social Sciences.

DISCUSSION

FORCE OR DURATION? To determine whether the force or the length of the noise plays the major role as the perceptive cues for aspiration, a number of experimental techniques were used. As the space of the present paper is limited, only a few selected examples are given here. Fig.1 and Fig.2 are histograms of the amplitudes measured from the acoustic records spoken by two subjects A and B (a male and a female). The amplitude of aspirated stops and affricates are shown somewhat stronger than that of unaspirated ones, especially in /pa/ and /pu/, where the explosion of unaspirated stops are too

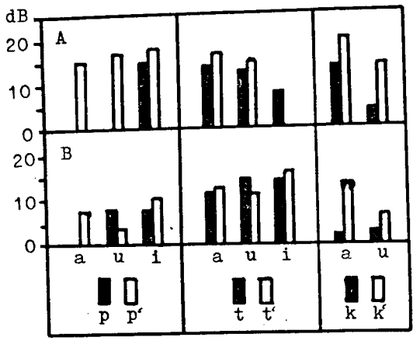

Fig.1 Histograms of the amplitude of non-aspirated and aspirated stops

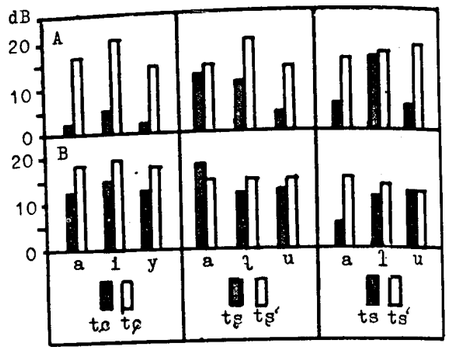

Fig.2 Histograms of the amplitude of non-aspirated and aspirated affricates

weak to be detected. But in the /p'u/, /t'u/, /ts'a/ and /ts'u/ spoken by B, the results turned out to be just in the contrary. As a whole, the difference in force between the aspirated and non-aspirated consonants are not so evident as commonly believed. In Fig.3 and Fig.4, great differences can be seen in the measurements between the length of the aspirated and non-aspirated consonants; that for the stops, the proportion of amplitude in the aspirated and non-aspirated stops is 11/7 and that of duration is 71/11, while for the affricates the proportion of amplitude in the two categories is 14/10 and the proportion of duration is 120/46. On the average, their differences are around 1.5 to 1 in amplitude and 3 or more to 1 in duration.

Table I gives the data of supraglottal air-pressure of both stops and affricates. There are no direct proportional relationship between aspirated and

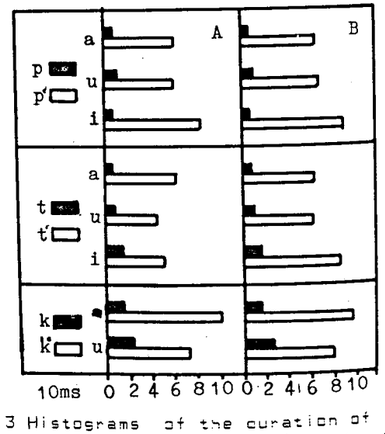

Fig.3 Histograms of the duration of non-aspirated and aspirated stops

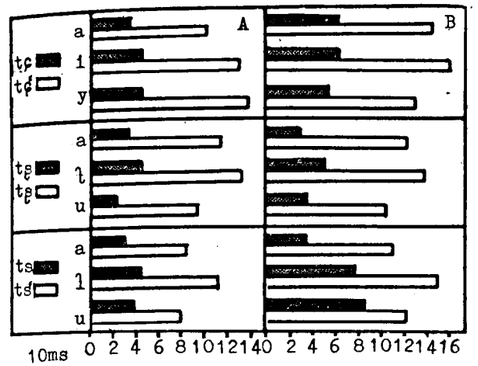

Fig.4 Histograms of the duration of non-aspirated and aspirated affricates

Table I Supraglottal air-pressure of stops and affricates in SC

		p	t	k	ts	tʂ	tɕ
Non-asp	A	10	90	-	11	89	14
	B	10	27	-	11	31	58
		p'	t'	k'	ts'	tʂ'	tɕ'
Asp	A	11	84	3	11	39	17
	B	10	24	-	19	10	25

Table II Supraglottal air-flow rate of stops and affricates in SC

		p	t	k	ts	tʂ	tɕ
Non-asp	A	-	54	-	50	-	-
	B	-	-	-	-	-	-
		p'	t'	k'	ts'	tʂ'	tɕ'
Asp	A	90	100	110	100	120	80
	B	100	50	90	100	120	80

non-aspirated consonants. Moreover, the proportion of pressure in /t'/ and /t/ is 84/90 and in /ts'/ and /ts/ is 39/89 by speaker A, and in /tʂ'/and /tʂ/ is 25/58 by B. The air-pressure of aspirated consonants is occasionally weeker rather than stronger than that of non-aspirated ones. Table II gives the data of supraglottal air-flow rates, which are directly proportional to the duration measured in the acoustic dimension. That is to say, the more the air-flow, the more the noise is prolonged. The difference in supraglottal air-flow between aspirated and non-aspirated consonants are much greater. It is easy to explain. In unaspirated stops, the explossive noise is short and is immediately followed by the vowel. There is occasionally a silent gap between CV instead of a noise. In unaspirated affricates, although the friction seems to be the results of air-flow, the air does not expel continuously out from the pulmonic cavity while the glottis keeps open. Mowover, the width of the glottis opening is much more smaller than that of aspirated affricates [7]. So their air-flow rate could hardly be measured.

SOUND SOURSE The aspiration of consonant is usually defined as a noise. On the acoustic point of view, questions might be raised as: what are characteristics of these noise? Are they all white-noise, or noise with different parameters?

In the spectrograms of these consonants, in an aspirated stop as /p'/, the aspirated section is a sequence of non-periodical noise, bearing the acoustic features similar to that of fricative /h/. i.e., the concentration areas are scattered and connected the formants of the following vowel with a /plain/ transitional feature. While in an aspirated affricates as /ts'a/, the sequence of noise is separated into two: the first part of the noise bears the same acoustic character as the fricative /s/, and the second part is the same as /h/. Thus a clear boundary between them is shown. But when an aspirated affricated followed by another vowel as in /ts'ɿ/, the noise is quite different from that in /ts'a/. It gives no /h/ noise but prolongs the /s/ friction. The same phenomina can be also found in /tʂ'ɿ/ and /tʂ'ʅ/ in Standard Chinese. These can be explained by the physiological interpretation. When the vowel after an aspirated affricate, if the tongue height is lower than that of the consonant as in /ts'a/, as soon as the constriction of /ts/ is released and the tongue moves to /a/, no turbulence will be produced with the tongue tip, then the aspiration has to be formed by another way, so a /h/ like turbulence is produced at the back area of the tongue. This can be seen in the X-ray films. But in /ts'ɿ/, when the vowel starts, the tongue position does not move far apart from the upper palate for the gesture of the vowel is homorganic with that of /ts' /, but the stricture is slightly enlarged and the turbulence is displayed by the voice.

PERCEPTION TEST In order to prove the results mentioned above, a number of perception tests are arranged through a synthesizer. Some of the consonants given in Fig.1-4 are sythesized by rule in which the aspirated sections are changed by double the amplitude or double the length of the friction. The parameters of the frictive part of the affricates are given based on the quality of /h/ or of the same as the friction of affricates. Fig.5 is a sample of an affricate /ts/ followed by an open vowel /a/. From left to right, /ts/ is a non-affricate, /tʂ/

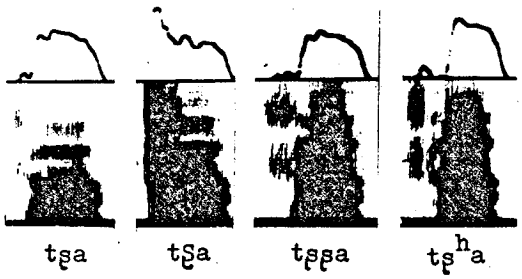

Fig.5 Spectrograms of synthesized affricates /tʂ/ in different manners followed by vowel /a/ (see text).

double the amplitude of /ʂ/, /tʂʂ/ double the length of /ʂ/ and /tʂh/, is /ts/ followd by /h/. The perception result is promissing in the last sample, and in which a boundary between the two frictions is prominantly seen. Fig.6 is a sample of affricate /tʂ/ followed by the vowel /ɿ/, and a /tɕ/ followed by the vowel /i/, both with their frictions doubled the length or followed by /h/; better results are obtained by doubled the lengths instead of plus a /h/.

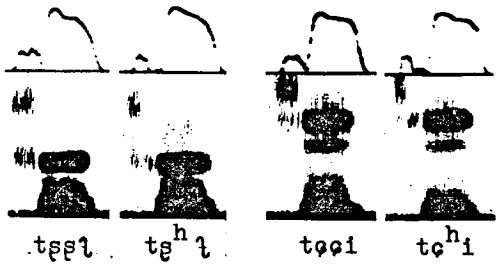

Fig.6 Spectrograms of synthesized affricates /tʂ/ and /tɕ/ in different manners followed by vowels /ɿ/ and /i/ respectively (see text).

It is interesting to have this results revealed in certain minority languages in China. For example, there are non-aspirated/aspirated pairs in Miao language of Guizhou, both the affricates and frictives can be aspirated. Fig.7 shows two pairs of "sa"/"s'a" and "ɕi"/"ɕ'i", in which we can see that "s'a" is "s" plus "h" with a boundary in the friction, while "ɕ'i" is a prolonged "ɕi" without any boundary in the friction.

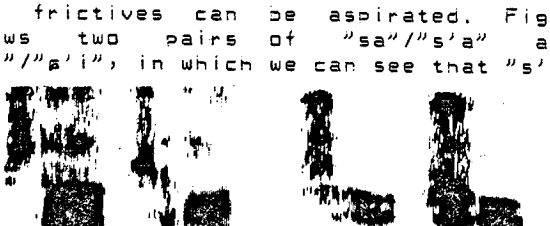

Fig.7 Spectrograms of non-aspirated and aspirated fricatives /s/ and /ɕ/ in Miao language.

CONCLUSION

The stops and the affricates in Standard Chinese exist two manners of articulation, non-aspirated and aspirated. The perception cues are mostly based upon the noise duration rather than the force. Moreover, the acoustic features of the aspirated noise are different in two types according to the following vowels. The aspiration is formed by adding a /h/ sound after release if it is followed by an open vowel; while formed by prolonging the length of noise if followed by a high vowel homorganic with the consonant.

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