UNDERSTANDING FLAPPING IN XIANGXIANG CHINESE: ACOUSTIC AND AERODYNAMIC EVIDENCE

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ABSTRACT

This paper investigated the phonetic nature of flapping for /d/ and /t^h/ in intervocalic pre-unstressed and pre-stressed positions at a normal speech rate in Xiangxiang Chinese. The resulting data were approached in two perspectives: acoustic and aerodynamic. It was found that the acoustic and aerodynamic patterns were significantly correlated with each other, and both showed that /d/ and /t^h/ exhibited considerable ***intra-speaker*** variation which constituted a continuum from typical [d]s and [t^h]s to typical flaps in intervocalic position, indicating an articulatory continuum from long and complete oral closure for typical [d]s and [t^h]s to short and incomplete oral closure for typical flaps. This mirrors a gradient process which springs from a single mechanism common to each speaker. A model of consonant-vowel co-articulation was proposed and other related problems raised by these results were also discussed.

Keywords: flap, acoustic, aerodynamic, continuum, consonant-vowel co-articulation

1. INTRODUCTION

The phonetic characteristics of "flaps" have been attracting the interests of many linguists in the past fifty years. Some studies made a distinction between "flaps" and "taps" while others did not. Following Catford [1], the present paper used "flap" as a cover term, and the consideration was mainly as follows: first, the essence of the definition of the two segments is their "momentariness", which makes them distinct from any other consonant articulation. Second, they share many acoustic characteristics such as short occlusion duration of 10-30 ms, the presence of formant structure during the occlusion, indicating an incomplete closure and the absence of clear release burst. (See [2], [3], [5], [6], [7] and [8]) Third, despite their subtle articulatory differences, Monnot and Freeman [4] found perceptual cross-identification of the two segments.

According to my preliminary impressionistic description, the flaps in Xiangxiang Chinese (hereafter XXC), a representative of the Old Xiang Dialects of Chinese, are allophones of /d/ and /t^h/ in intervocalic pre-unstressed position. The purpose of the present study was to investigate the nature of flapping in XXC in two perspectives: acoustic and aerodynamic, and to try to account for this process within a plausible and general model.

2. METHODOLOGY

The test material contained 72 bi-syllabic words with intervocalic /d/ or /t^h/ in both pre-unstressed and pre-stressed positions (VdV, Vt^hV). Five speakers, four male and one female, provided the speech data. They are all native speakers of XXC and age between 25 and 30 years. The recording consisted of two sessions: acoustic and aerodynamic, and the speakers were instructed to read the randomized test words three times at a normal speech rate, resulting in a total of 1080 (72×3×5) tokens for each session. The acoustic data was gathered by using a Sony PCM-R700 digital audio recorder and a Shure SM-58 microphone. The airflow data was collected by using the Scicon PCquirer.

3. RESULTS

3.1. Acoustic data

Examination of the acoustic characteristics of the intervocalic /d/ and /t^h/ showed several patterns.

3.1.1 Intervocalic /d/

/d/ exhibits considerable intra-speaker variation which constituted a continuum from typical [d]s to typical flaps in intervocalic position. Four types of variation were detected for /d/. The first type has a voiced occlusion of long duration and a clear release burst. Weak formant structure may or may not be present during the closure. The fourth type has a voiced occlusion of short duration and formant structure during the occlusion, and lacks a release burst. The second type differs from the

fourth type only in duration, so does the third type differ from the first type. A close look at the mean duration of the four variants reveals a continuum from about 10-30 ms for the third and fourth types to about 30-60 ms for the first and second types. The four patterns of variation described above are defined as a typical [d], a long flap, a short [d] and a typical flap respectively by the acoustic criterion implicated in [3], according to which the strongest perceptual correlate of a separation of voiced stops and flaps is the presence or absence of a salient release burst. The first and fourth types correspond to the two ends of the continuum, and the second and third types, which appear to compromise acoustic characteristics of both ends, correspond to the middle of the continuum. The relative position of the two median types along this continuum, however, is unknown.

Figures 1-4 illustrates the waveforms and spectrograms of the four acoustic patterns observed for intervocalic /d/. Figure 1 shows a typical [d] of 49 ms, and we can see that with the presence of a clear release burst, modal voicing is disturbed during the burst. In Figure 2, which illustrates a long flap of 56 ms, there is no clear release burst that can be observed, indicating that during its production the articulators do not form a complete closure, and therefore the release of this incomplete occlusion is not abrupt, at least less so as compared with a stop. Figure 3 is a short [d], with the duration of 22 ms and a clear release burst. Figure 4 shows a typical flap, which has a short duration of 20 ms and no release burst. The waveforms for flaps exhibit a momentary decrease in amplitude of the preceding and following vowels. Figures 1 to 4 exhibit an acoustic continuum with typical [d]s and typical flaps constituting the two ends, and long flaps and short [d]s corresponding to the middle of the continuum.

Figure 1: Typical [d]

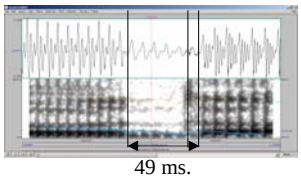


Figure 2: Long flap

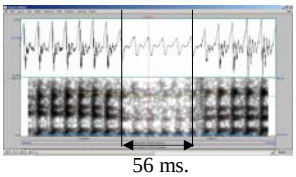


Figure 3: Short [d]

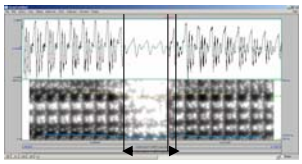
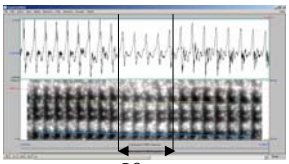


Figure 4: Typical flap



Two tokens of /d/ between [u] and [a] for Speaker 4 are illustrated in Figure 5 and 6. A comparison of the waveforms of the two tokens reveals that the variant in Figure 6 has amplitude as high as the preceding and following vowels, instead of a momentary decrease in amplitude of the neighboring vowels for the typical flap in Figure 5, indicating that the articulators in Figure 6 are as open as the neighboring vowels. The alveolar tongue gesture, however, is approached for the variant in Figure 6, as evidenced by the formant structure typical of an alveolar articulation: F1=473Hz, F2=1437Hz, F3=2759Hz, similar to that of the typical alveolar flap in Figure 5: F1= 386Hz, F2= 1407Hz, F3= 2818 Hz. The variant in Figure 6 represents a production of shortest duration and least degree of oral closure, and therefore stands at the extreme right end of the continuum for the intervocalic /d/.

Figure 5: A typical flap

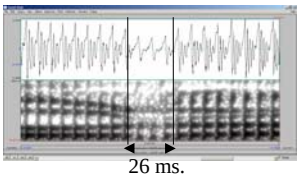
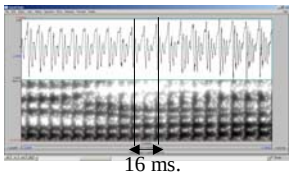


Figure 6: An extreme case



3.1.2 Intervocalic /t^h/

Intervocalic /t^h/ also exhibits considerable intra-speaker variation. There are five types of variants observed for each speaker: typical [t^h], typical [d^h], short [d^h], long and typical aspirated flap. A close look at the mean duration of the intervocalic /t^h/s shows a continuum from about 10-30 ms for short [d^h]s and flaps to about 30-60 ms for typical [d^h]s and long voiced aspirated flaps, and then to about 60-120 ms for typical [t^h]s.

Figures 7-11 illustrate the waveforms and spectrograms of the five acoustic patterns observed for intervocalic /t^h/: for each pattern, the figure on the left displays the whole bi-syllabic word with intervocalic /t^h/, and the one on the right gives an enlarged view of /t^h/ marked by the vertical lines. Figure 7 is a typical [t^h] with long duration of closure and release. Figure 8 is a typical [d^h], with a clear release burst indicated by the sudden appearance of breathy noise superimposed on the regular waveform. Figure 9 is a short [d^h] which is different from Figure 8 only in duration. Figures 10 and 11 show a long and a typical aspirated flap respectively, with breathy noise superimposed on the regular waveform throughout the production, which is very interesting for a voiced aspirated flap

has not been reported in the literature. Also note that the aspiration of all variants of /t^h/ continues into the initial part of the following vowel.

Figure 7: Typical [t^h]

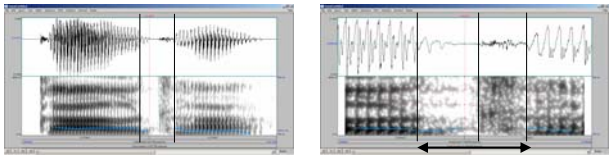


Figure 8: Typical [d^h]

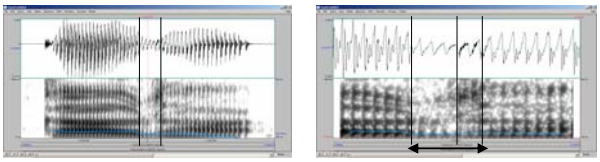


Figure 9: Short [d^h]

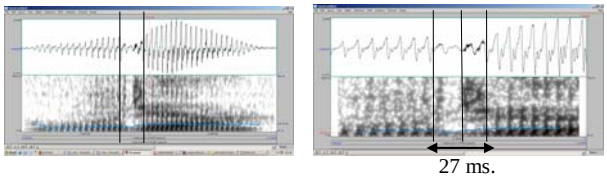


Figure 10: Long aspirated flap

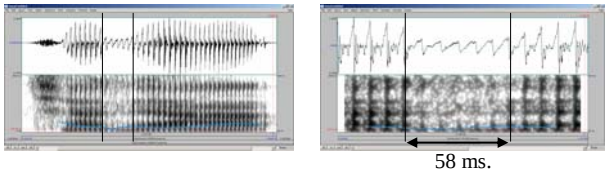
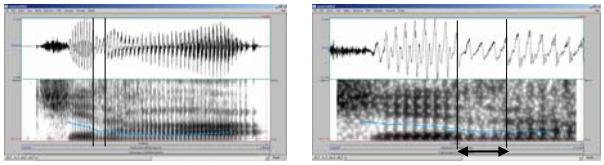


Figure 11: Typical aspirated flap



3.2. Aerodynamic data

The results of the aerodynamic experiment show that the patterns of oral airflow are significantly related with the acoustic patterns. For the variant of a typical [d] and a short [d] for intervocalic /d/, there is little or no oral airflow during the voiced closure period, resulting in the presence or absence of weak formant structure during the occlusion period. At the onset of release, there is an abrupt increase of oral airflow, indicating the appearance of an abrupt and clear release burst. This is shown in Figure 12. For the variants of long or typical flaps, there is a slight decrease of oral airflow of the preceding and following vowels, which indicates an incomplete closure of the articulators and the absence of a clear release burst, as shown in Figure 13. Figure 15 gives the oral airflow pattern of the extreme acoustic case in Figure 6 (repeated in Figure 14) which has amplitude as high as the preceding and following vowels. The oral airflow pattern of this extreme case shows that during its production there is no decrease of oral airflow of the preceding and following vowels, indicating that the articulators are as open as the neighboring vowels, and this variant, therefore, stands at the extreme right end of an articulatory continuum from complete to no oral closure.

Figure 12: [d]

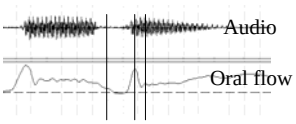


Figure 13: Flap

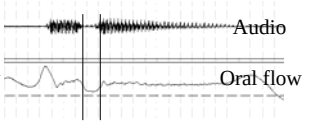


Figure 14: Extreme case (acoustic)

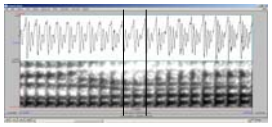
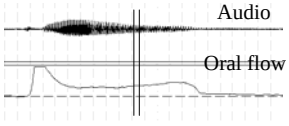


Figure 15: Extreme case (aerodynamic)



For the intervocalic /t^h/, the variant of a typical [t^h], as shown in figure 16, has a clear voiceless occlusion period with oral airflow reaching zero, a clear release burst indicated by an abrupt rise of oral airflow and an aspiration period with oral airflow staying high. Typical and short [d^h]s differ from typical [t^h]s in that they have voicing throughout their production, with much shorter occlusion and aspiration periods, as illustrated in Figure 17. For voiced aspirated flaps, there is either high oral airflow throughout, as high as during the aspiration period of a typical [t^h] (Figure 18), or a rise of oral airflow is observed from the onset of flap production to the initial part of the following vowel (Figure 19).

Figure 16: [t^h]

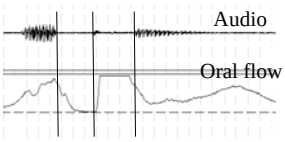


Figure 17: [d^h]

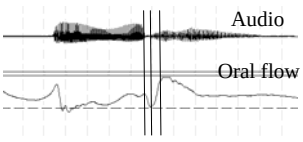


Figure 18: Aspirated flap (1)

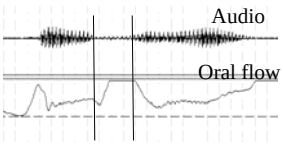
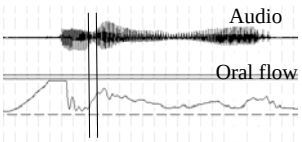


Figure 19: Aspirated flap (2)



4. DISCUSSION AND CONCLUSION

This paper investigates the phonetic nature of flapping for /d/ and /t^h/ in intervocalic pre-unstressed and pre-stressed positions at a normal speech rate in XXC. It was found that the acoustic and aerodynamic patterns were significantly correlated with each other, both showing that /d/ and /t^h/ exhibit considerable ***intra-speaker*** variation which constitutes a continuum from typical [d]s to typical flaps for /d/ and typical [t^h]s to typical aspirated flaps for /t^h/ in intervocalic position, with long flaps and short [d]s standing in the middle of the continuum for /d/, and typical [d^h]s, short [d^h]s and long aspirated flaps in the middle of the continuum for /t^h/. This observation shows that the articulation of the intervocalic /d/ and /t^h/ does not mirror the discrete phonological modeling of the flapping process where the alveolar stop is replaced wholesale by a flap, but a gradient process for each individual speaker. Since the continuum emerges for each speaker, flapping may spring from a single mechanism common to all speakers of XXC. The impressionistic description of flaps as an allophone of intervocalic /d/ or /t^h/ may be based on the observation that underlying alveolar consonants show up auditorily as a categorically different entity, flaps. Thus the formulation of a categorical rule may just be the result of categorizing the acoustic results of gradient changes in articulation in terms of categorical differences found in other languages. [3]

Stress does not seem to be the possible factor that conditions flapping, since the continuum of intervocalic /d/ and /t^h/ is observed in both pre-unstressed and pre-stressed positions for each speaker. The acoustic and aerodynamic continuum indicates an articulatory one from long and complete oral closure for typical [d]s and [t^h]s to short and incomplete oral closure for typical flaps. Recall the variant for /d/ which has comparatively high amplitude (illustrated in Figure 14) and oral airflow (illustrated in Figure 15) as the neighboring vowels, indicating that articulatorily it has a comparatively open oral tract as the neighboring vowels, therefore representing an extreme case in the continuum from complete to no oral closure. The intra-speaker variation of intervocalic /d/ and /t^h/ may then well be explained by a model of consonant-vowel co-articulation: the consonant is in close proximity of two vowels that demand an open vocal tract, thus the intra-speaker continuum from closed to open oral tract may just be the result of consonant-vowel co-articulation. This mechanism is likely to be located at speakers' phonetic representation, a level which permits non-categorical and gradient variation, with the variant of typical [d]s and [t^h]s which have a closed oral tract being the case of least degree of CV co-articulation, and the variant of flaps which have an open oral tract being the case of considerable CV co-articulation.

Flaps can involve different laryngeal features: this paper finds that flaps can be voiced aspirated, which has not been reported in the literature.

There is one observation that needs to be accounted for in the future study. There is a three-way distinction of stops in XXC: voiceless unaspirated, voiceless aspirated and voiced, and /t^h/ patterns with /d/ instead of /t/ by undergoing the flapping process. It is very interesting for by assumption it would be more "reasonable" for /t^h/ to pattern with /t/ for they share the same voicing feature. This patterning is further illustrated in the historical relationship between tone and initial obstruents: the historical voiced and voiceless aspirated obstruents in XXC pattern together by having an effect of pitch lowering. A plausible phonetic explanation of this finding is the focus of my future study.

5. REFERENCES

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