Declination and supra-laryngeal articulation in Cantonese – EPG study

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Abstract

Supra-laryngeal declination was reported in Italian and English. Such findings suggest that declination is not confined to the laryngeal sub-system and its acoustic output --- F_0. This paper intended to examine the supra-laryngeal articulation and declination in Hong Kong Cantonese (a tone language) and tested whether declination also affect supra-laryngeal articulation. In light of recent findings in the effect of prosodic positions on articulation, it is the second goal of this paper to investigate any interaction of prosodic positions and declination on supra-laryngeal articulation. Results showed no supra-laryngeal declination; however, declination interacts with prosodic positions in F_0 scaling.

1. Introduction

Declination studies have focused mainly on fundamental frequency in phonetics and phonology literature, for example, Pierrehumbert 1979, 't Hart, Collier & Cohen 1990, Cooper & Sorensen 1981. There are studies showing that declination as a function of utterance positions in speech affects supra-laryngeal behaviour as well, for example, Fowler 1988, Vatikiotis-Bateson & Fowler 1988, Vayra & Fowler 1992, Krakow, Bell-Berti and Wang 1995. In other words, declination is not confined to the laryngeal sub-system, suggesting that declination is a more general phenomenon in speech production. Vayra and Fowler (1992) showed that the open vowel /a/ became less open in the last syllable than in the first syllable of bi- and tri-syllabic Italian pseudo-words. The observation is interpreted as an effect of declination, because of reduced energy and increased relaxation of the tongue movement in the latter part of an utterance.

At the same time, there are studies showing that prosodic positions also affect phonetic properties of individual segments, for example, Fougeron & Keating 1997 and Cho 1998. In light of such findings, it is not clear whether supra-laryngeal declination results from difference in utterance positions or prosodic positions.

The current study is an attempt to extend the findings in non-tonal languages to a tone language Cantonese and examine the effects of declination and prosodic positions on both f0 and supra-laryngeal articulation.

2. Experimental design

Electropalatographic data were collected from two Cantonese speakers in a production experiment. Speakers wore an artificial palate embedded with 62 electrodes to record tongue-palate contact. There was a 10-minute acclimatisation period for both subjects before the reading experiment began. Recording was conducted in a recording studio at Queen Margaret University College. There were nine test sentences in each block. Each block was repeated ten times. There was an inter-block interval of 2 minutes. The whole recording took about 35-40 minutes to complete.

2.1. Stimuli

The target word under investigation was the Cantonese numeral "sam" (gloss: three). The target numeral "sam" was used to form three numerical expressions – "sam sep sam" (gloss: thirty-three); "sam ko sam" (gloss: three point three); and "sam ji sam" (gloss: three two three). It should be noted that the first and the last numeral of the three numerical expressions was the same word "sam". This target numeral "sam" was embedded in six positions as underlined in a nineteen-word test carrier sentence, as illustrated below:

Six Target Utterance Positions:

Positions P1 P2 P3 P4 P5 P6 P7 P8 P9 P10 P11
P12 P13 P14 P15 P16 P17 P18 P19
Word sam ko sam ga sam ko sam ga sam ko sam
ga ga mai mai dzou hai hou do
Numerical Unit
(unit. 1) (unit. 2) (unit. 3)
Tone H HM H H H HM H H H HM H
H H L L HM ML H
Gloss 3.3 + 3.3 + 3.3 altogether = a lot.

Three Prosodic structures were devised with each of the three numerical expressions, as illustrated below:

Three Prosodic Structures:

Positions (P1 P2 P3) P4 (P5 P6 P7) P8 (P9 P10 P11)
P12 P13 P14 P15 P16 P17 P18 P19
Positions within each Numerical Unit
(initial final) (initial final) (initial final)

a) Equal/Control:
(3.3) + (3.3) + (3.3) altogether = a lot.
Prosodic Positions within each Phrase
(initial final) (initial final) (initial final)

b) Left-complex:
(3.3 + 3.3) + (3.3) altogether = a lot.
Prosodic Positions within each Phrase
(initial medial medial final) (initial final)

c) Right-complex:
(3.3) + (3.3 + 3.3) altogether = a lot.
Prosodic Positions within each Phrase
(initial final) (initial medial medial final)

2.2. Predictions

The first goal of the current study is to investigate whether declination as a function of utterance positions will affect supra-laryngeal articulation. By means of electropalatography, we will measure the tongue-palate contact during the production of vowel /a/ in the target numeral /sam/. As /a/ is a low vowel, we will expect little tongue-palate contact in a normal rest position. In light of findings from Vayra and Fowler (1992), we will predict that declination will result in a more relaxed and weakened articulation of the vowel /a/. In other words, more tongue-palate contact is expected. If declination affects supra-laryngeal articulation in the direction of hypo-articulation, the target vowel /a/ will increase the tongue-palate contact as a function of utterance positions.

The second goal is to investigate whether the prosodic structure, particularly the phrase boundary, will interact with declination. The second numerical unit in the sequence of three numerical units was manipulated to induce a boundary between the second and third numerical units in the Left-complex condition; and a boundary between the first and the second numerical units in the Right-complex condition. At the same time, the utterance positions of the target numerical units were kept constant. In light of the findings from Fougeron and Keating (1997), we will predict that the articulation of vowel /a/ is stronger in a phrase domain-initial position at the boundary juncture than in a phrase domain-non-initial position. The strong articulation of vowel /a/ will be manifested by a more extreme and open articulation. That means, fewer tongue-palate contact for the vowel /a/ is expected between the second and the third numerical units in the Left-complex condition; and between the first and the second numerical units in the Right-complex condition.

3. Results and Discussion

Both EPG and F_0 data were used to test for the effects of utterance positions and prosodic positions.

3.1. EPG Analysis

The maximum total EPG contact on /a/ was recorded. The EPG contact was ranged between 0 and 1, with 0 meaning no tongue-palate contact and 1 full tongue-palate contact. Both speakers showed that the Mean total EPG contact on /a/ increased from utterance position 1 to position 3; a similar pattern of increasing EPG contact was also found from position 5 to position 7. The same can be said of the EPG contact from position 9 to position 11. The pattern can be seen in Table 1.

Table 1. *Mean Total EPG contact in six test utterance positions for both speakers.*

Speakers	Pos.1	Pos.3	Pos.5	Pos.7	Pos.9	Pos.11
1(Male)	0.138	0.223	0.148	0.212	0.153	0.218
2(Fem.)	0.145	0.197	0.151	0.193	0.155	0.194

The data showed that two groups emerge. Group 1 with target word /sam/ in utterance position 1, 5 and 9; group 2 with the corresponding target word /sam/ in position 3, 7 and 11. Group 1 exhibited fewer total EPG contact than group 2. The greater EPG contact on the target vowel /a/ means that the target vowel tends to be more hypo-articulated. It should be noted that the target word in position 1, 5 and 9 occurred in the initial position of each test numerical unit; whereas the target word in group 2 occurred in the final position of each test numerical unit. Our data therefore showed that the target vowel /a/ in the initial position of each test numerical unit exhibited a more precise and hyper-articulated vowel than its counterpart in the final position of the corresponding numerical unit.

ANOVAs (Repeated Measures) were done separately for each individual speaker, with prosodic structures (3 levels) and Utterance Positions (6 levels) as independent variables. The dependent variable was the Total maximum EPG contact. The effect of Utterance Positions reached significance for both Speaker 1 (male) and Speaker 2 (female). There was also a significant interaction between Utterance Positions and Prosodic Structures. Details can be found in Table 2.

Table 2. *ANOVA results for both speakers (EPG data)*

Speakers	Positions	Structures	Pos.*Structures
1(male)	F=57.018,df=5 P<0.0001	n.s.	F=2.92, df=10 P<0.001
2(fem.)	F=15.494,df=4.46 P<0.0001	n.s.	F=3.981,df=9.9 P<0.0001

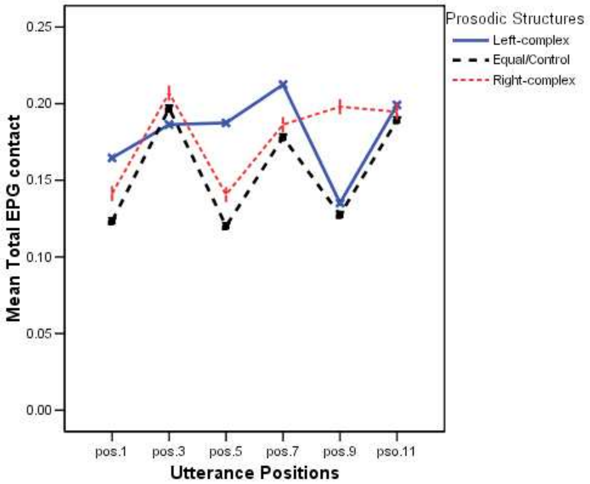
The significant effect of Utterance Positions is due to the difference between EPG contact in Positions 1, 5 and 9 as a group and that in Positions 3, 7 and 11 as another group.

If declination as a function of utterance positions affects supra-laryngeal articulation, we will expect a gradual weakening of articulation of vowel /a/ from position 1 to position 11. However, our data did not suggest the prediction of gradual articulatory weakening of /a/ in successive utterance positions. Instead, articulatory weakening seems to depend on whether the utterance position, in which the target vowel occurs, coincides with the initial position of the numerical unit or not.

There was no significant difference in the Total EPG contact among the three Prosodic Structures, meaning that the EPG contact averaged across all six test utterance positions is similar in all three Prosodic Structures.

However, the significant interaction suggests that Prosodic Structures affect the Total EPG contact in various test utterance positions. Figure 1., taken from Speaker 2, showed more EPG contact in Position 5 in the Left-complex condition than in the Equal/Control and Right-complex conditions. In the Left-complex condition, the target word in Position 5 is also in a phrase-medial position, as opposed to a phrase-final position in both the Equal/Control and Right-complex conditions. Similarly, there was more EPG contact in Position 9 in the Right-complex condition than in the Equal/Control and Left-complex conditions, because the target word in Position 9 in the Right-complex condition also occurred in a phrase-medial position, as opposed to a phrase-initial position in both the Equal/Control and Left-complex conditions. These observations suggest that the target vowel /a/ in a phrase-medial position was hypo-articulated, but not so for its counterparts in both phrase-initial and phrase-final positions.

Figure 1. *Interaction of Positions and Prosodic Structures on EPG contact (Speaker 2).*



A similar EPG pattern was observed in Speaker 1 as well, though Speaker 1 did not weaken the articulation of vowel /a/ as much as that observed in Speaker 2 in Position 5 in the Left-complex condition and in Position 9 in the Right-complex condition.

3.2. F_0 analysis

F_0 was measured at the end of the nucleus in the target word /sam/ in six test utterance positions. Table 3 summarized the F0 values of the test words in six utterance positions in three Prosodic Structures for both speakers.

Table 3. *Summary of F_0 values for six utterance positions in three Prosodic Structures*

Spk	Struct-ures	Pos. 1 Hz.	Pos. 3 Hz.	Pos. 5 Hz.	Pos. 7 Hz.	Pos. 9 Hz.	Pos. 11 Hz.
1m	Eq/Con	124	101	98	87	90	83
	L-comp	124	103	97	86	96	83
	R-comp	124	100	110	92	89	83
2f	Eq/Con	243	219	223	219	214	200
	L-comp	257	232	216	202	219	199
	R-comp	240	217	240	221	208	195

As seen in Table 3., both speakers exhibited the well-reported declination. Speaker 1 dropped his F_0 from 124 Hz in Position 1 to 83 Hz in Position 11 --- a total of 41 Hz in all three test Prosodic Structures. Speaker 2 decreased a total of 43 Hz from Position 1 to Position 11 in the Equal/Control condition; a total of 57 Hz in the Left-complex condition and a total of 45 Hz in the Right-complex condition.

It was observed that the Prosodic Structures also affect how F_0 is scaled in the six target successive positions. F_0 value was increased from Position 3 to Position 5 in the Right-complex condition. Speaker 1 increased from 100 Hz in Position 3 to 110 Hz in Position 5 (an increase of 10 Hz); and speaker 2 from 217 Hz to 240 Hz (an increase of 23 Hz). In the Right-complex condition, the target word in Position 3 is phrase-final; whereas the target word in Position 5 is phrase-initial. The target word in the phrase-initial position induced an F_0 reset in Position 5, thereby reverting an overall declination.

Figure 2. *Interaction of Prosodic Structures and Positions on F_0 (Speaker 1)*

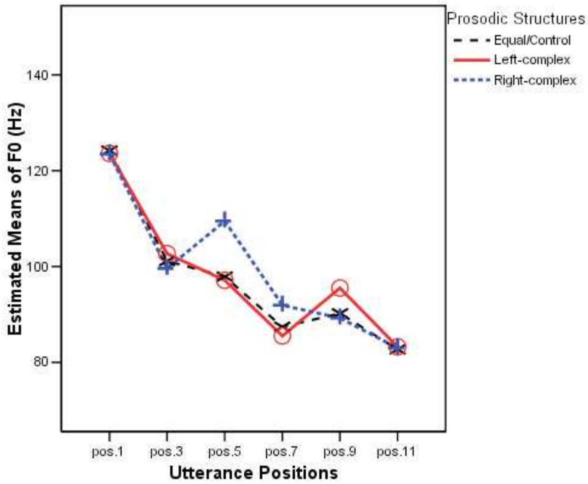
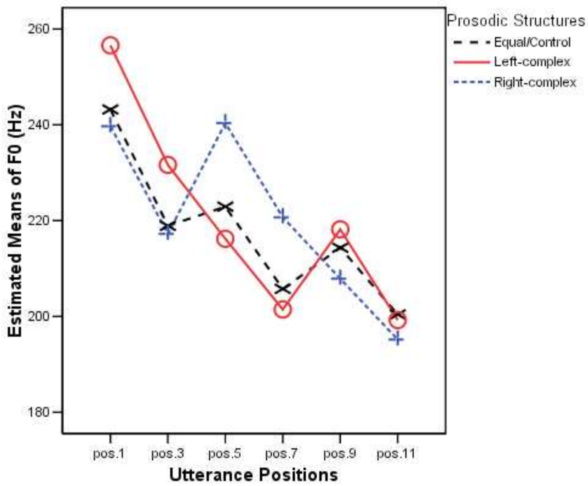


Figure 3. *Interaction of Prosodic Structures and Positions on F_0 (Speaker 2)*



A similar pattern can be observed in the Left-complex condition between Position 7 and Position 9. Speaker 1 exhibited an increase of 10 Hz; and Speaker 2 an increase of 17 Hz. The increase in F_0 resulted from the difference in the prosodic positions --- Position 7 is phrase-final and Position 9 is phrase-initial. In other words, the presence of a phrase juncture (boundary) resulted in F_0 reset.

However, F_0 reset at the phrase juncture (boundary) in both the Left-complex and the Right-complex conditions is only partial, as illustrated in Figures 2 and 3. Declination affects the scaling of F_0 of the target word /sam/ in the phrase-initial position after the phrase juncture in both Left-complex and Right-complex conditions. The target word in the phrase-initial position after the phrase boundary in the Left-complex condition occurs later than that in the Right-complex condition. This resulted in a lower F_0 reset in the former than in the latter .

At the same time, F_0 reveals that there was some degree of F_0 reset from Position 3 to Position 5, and from Position 7 to Position 9 in Equal/Control condition. Auditory impressions indicated that both speakers inserted a pause after Position 3 and another after Position 7. In other words, both speakers produced the test sentences in Equal/Control condition with two phrase junctures --- one after Position 3 and another after Position 7.

Repeated ANOVAs were conducted for each speaker, with Utterance Positions and Prosodic Structures as Independent variables, and F_0 as Dependent variable. As seen in Table 4, a significant effect of Utterance Positions was found in both speakers, indicating the presence of declination. No significant effect of Prosodic Structures was found. However, there was a significant interaction between Utterance Positions and Prosodic Structures in both speakers. It suggests that the location of the phrase boundary in different conditions affects the F_0 in various test utterance positions in different ways.

Table 4. *ANOVA results of F_0 for both speakers*

Speakers	Positions	Structures	Pos.*Structures
1(male)	F=1259.7,df=3.76 P<0.0001	n.s.	F=26.17, df=7.5 P<0.0001
2(fem.)	F=1201.695,df=5 P<0.0001	n.s.	F=121.27,df=10 P<0.0001

4. Conclusions

Our F_0 data shows declination in line with findings in [5] and [9] and additionally its interaction with prosodic structures, particularly after a phrase boundary. After a phrase boundary, the F_0 in the phrase-initial position is reset. Yet, declination affects the magnitude of F_0 reset. On the other hand, our EPG data do not provide evidence for supra-laryngeal declination as reported in [5]. There was no articulatory weakening in producing successive /a/s in our data set. The only articulatory weakening we observed in successive /a/s is derived from the difference between a more peripheral /a/ in the initial position and a hypo-articulated /a/ in the final position of each numerical unit. Such numerical unit is intermediate between a word and a phrase. Given our data, it is possible to reinterpret findings in [5] as the effect of prosodic position, since in [5] supra-laryngeal declination was based on the sentence-initial and the sentence-final positions. The current study shows that prosodic positions affect supra-laryngeal sub-system, whereas both prosodic positions and declination (as a function of utterance positions) affect the laryngeal sub-system.

5. References

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